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**Department of Defense
Fiscal Year (FY) 2020 Budget Estimates**

March 2019



Air Force

Justification Book Volume 1 of 3

Research, Development, Test & Evaluation, Air Force

Vol-I

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Air Force • Budget Estimates FY 2020 • RDT&E Program

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Fiscal Year (FY) 2020 Budget Estimates RDT&E Descriptive Summaries Budget Activities March 2019

INTRODUCTION AND EXPLANATION OF CONTENTS

GENERAL

- This document has been prepared to provide information on the United States Air Force (USAF) Research, Development, Test and Evaluation (RDT&E) program elements and projects in the FY 2020 President's Budget.
 - All exhibits in this document have been assembled in accordance with DoD 7000.14R, Financial Management Regulation, Volume 2B, Chapter 5.
 - Other comments on exhibit contents in this document:
 - Exhibits R-2/2a and R-3 provide narrative information for all RDT&E program elements and projects within the USAF FY 2020 RDT&E program with the exception of classified program elements. The format and contents of this document are in accordance to the guidelines and requirements of the Congressional committees in so far as possible.
 - The "Other Program Funding Summary portion of the R-2 includes, in addition to RDTE& funds, Procurement funds and quantities, Military Construction appropriation funds on specific development programs, Operations and Maintenance appropriation funds where they are essential to the development effort described, and where appropriate, Department of Energy (DOE) costs.

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- All exhibits contained in Volumes I, II, and III are unclassified. Classified exhibits are not included in the submission due to the level of security classification and necessity of special security clearances.

RDT&E, Air Force Overseas Contingency Operations (OCO)

- FY2020 OCO can be separated into the following categories:
 - OCO for Direct War Costs (\$44,335,000): Direct War costs are those combat or direct combat support costs that will not continue to be expended once combat operations end at major contingency locations.
 - OCO for Enduring Requirements (\$83,913,000): OCO for Enduring Requirements are enduring in-theater and in-CONUS costs that will likely remain after combat operations cease, and have previously been funded in OCO.
 - OCO for Base Requirements (\$322,000,000): OCO for Base Requirements is OCO funding for base budget requirements in support of the National Defense Strategy. The Budget requests these funds in OCO to comply with the base budget defense caps included in the Budget Control Act of 2011.

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Department of Defense
 FY 2020 President's Budget
 Exhibit R-1 FY 2020 President's Budget
 Total Obligational Authority
 (Dollars in Thousands)

19 Feb 2019

Appropriation -----	FY 2018 (Base + OCO) -----	FY 2019 Base Enacted -----	FY 2019 OCO Enacted -----	FY 2019 Total Enacted -----
Research, Development, Test & Eval, AF	38,077,597	41,166,683	321,934	41,488,617
Total Research, Development, Test & Evaluation	38,077,597	41,166,683	321,934	41,488,617

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19 Feb 2019

Appropriation	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)
Research, Development, Test & Eval, AF	45,616,122	322,000	128,248	450,248	46,066,370
Total Research, Development, Test & Evaluation	45,616,122	322,000	128,248	450,248	46,066,370

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 (Dollars in Thousands)

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Summary Recap of Budget Activities -----	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted
Basic Research	491,502	561,329		561,329
Applied Research	1,454,070	1,480,573		1,480,573
Advanced Technology Development	829,525	928,747		928,747
Advanced Component Development & Prototypes	4,962,068	6,625,697	13,495	6,639,192
System Development & Demonstration	4,407,341	5,453,523		5,453,523
Management Support	3,490,712	2,963,117		2,963,117
Operational Systems Development	22,442,379	23,153,697	308,439	23,462,136
Total Research, Development, Test & Evaluation	38,077,597	41,166,683	321,934	41,488,617
Summary Recap of FYDP Programs -----				
Strategic Forces	784,917	1,018,923	34,000	1,052,923
General Purpose Forces	2,899,628	3,077,252	53,049	3,130,301
Intelligence and Communications	1,609,415	1,438,024	54,600	1,492,624
Mobility Forces	550,926	898,833		898,833
Research and Development	11,665,345	12,799,979		12,799,979
Central Supply and Maintenance	97,493	96,826		96,826
Training Medical and Other	2,558	2,578		2,578
Administration and Associated Activities	118,914	122,255		122,255
Support of Other Nations	4,418	3,998		3,998

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Summary Recap of Budget Activities	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)
-----	-----	-----	-----	-----	-----
Basic Research	529,761				529,761
Applied Research	1,435,626				1,435,626
Advanced Technology Development	839,153				839,153
Advanced Component Development & Prototypes	8,436,279		44,335	44,335	8,480,614
System Development & Demonstration	6,929,244				6,929,244
Management Support	2,916,571				2,916,571
Operational Systems Development	24,529,488	322,000	83,913	405,913	24,935,401
Total Research, Development, Test & Evaluation	45,616,122	322,000	128,248	450,248	46,066,370
Summary Recap of FYDP Programs					
-----	-----	-----	-----	-----	-----
Strategic Forces	879,977				879,977
General Purpose Forces	3,488,992		5,200	5,200	3,494,192
Intelligence and Communications	1,393,298				1,393,298
Mobility Forces	979,221				979,221
Research and Development	14,419,778		26,450	26,450	14,446,228
Central Supply and Maintenance	37,505				37,505
Training Medical and Other	3,542				3,542
Administration and Associated Activities	90,730				90,730
Support of Other Nations	4,071				4,071

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	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted
Space	3,554,350	4,848,491	18,495	4,866,986
Classified Programs	16,789,633	16,859,524	161,790	17,021,314
Total Research, Development, Test & Evaluation	38,077,597	41,166,683	321,934	41,488,617

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 FY 2020 President's Budget
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	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)
Space	6,289,502		17,885	17,885	6,307,387
Classified Programs	18,029,506	322,000	78,713	400,713	18,430,219
Total Research, Development, Test & Evaluation	45,616,122	322,000	128,248	450,248	46,066,370

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Administration and Associated Activities	118,914	122,255		122,255
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Summary Recap of Budget Activities	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)
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Applied Research	1,435,626				1,435,626
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Advanced Component Development & Prototypes	8,436,279		44,335	44,335	8,480,614
System Development & Demonstration	6,929,244				6,929,244
Management Support	2,916,571				2,916,571
Operational Systems Development	24,529,488	322,000	83,913	405,913	24,935,401
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Summary Recap of FYDP Programs					
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Strategic Forces	879,977				879,977
General Purpose Forces	3,488,992		5,200	5,200	3,494,192
Intelligence and Communications	1,393,298				1,393,298
Mobility Forces	979,221				979,221
Research and Development	14,419,778		26,450	26,450	14,446,228
Central Supply and Maintenance	37,505				37,505
Training Medical and Other	3,542				3,542
Administration and Associated Activities	90,730				90,730
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Summary Recap of Budget Activities -----	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted
Space	3,554,350	4,848,491	18,495	4,866,986
Classified Programs	16,789,633	16,859,524	161,790	17,021,314
Total Research, Development, Test & Evaluation	38,077,597	41,166,683	321,934	41,488,617

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Summary Recap of Budget Activities	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)
Space	6,289,502		17,885	17,885	6,307,387
Classified Programs	18,029,506	322,000	78,713	400,713	18,430,219
Total Research, Development, Test & Evaluation	45,616,122	322,000	128,248	450,248	46,066,370

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Appropriation: 3600F Research, Development, Test & Eval, AF

Line No	Program Element Number	Item	Act	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted	Se
1	0601102F	Defense Research Sciences	01	320,961	383,322		383,322	U
2	0601103F	University Research Initiatives	01	157,079	164,991		164,991	U
3	0601108F	High Energy Laser Research Initiatives	01	13,462	13,016		13,016	U
		Basic Research		491,502	561,329		561,329	
4	0602102F	Materials	02	143,900	181,373		181,373	U
5	0602201F	Aerospace Vehicle Technologies	02	151,637	160,461		160,461	U
6	0602202F	Human Effectiveness Applied Research	02	126,542	119,018		119,018	U
7	0602203F	Aerospace Propulsion	02	192,846	218,419		218,419	U
8	0602204F	Aerospace Sensors	02	157,078	171,307		171,307	U
9	0602212F	Defense Laboratories R&D Projects (10 U.S.C, Sec 2358)	02	74,760				U
10	0602298F	Science and Technology Management - Major Headquarters Activities	02	8,353	8,288		8,288	U
11	0602601F	Space Technology	02	145,921				U
12	0602602F	Conventional Munitions	02	99,543	112,841		112,841	U
13	0602605F	Directed Energy Technology	02	121,610	141,800		141,800	U
14	0602788F	Dominant Information Sciences and Methods	02	191,724	185,276		185,276	U
15	0602890F	High Energy Laser Research	02	40,156	43,192		43,192	U
16	1206601F	Space Technology	02		138,598		138,598	U
		Applied Research		1,454,070	1,480,573		1,480,573	

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19 Feb 2019

Appropriation: 3600F Research, Development, Test & Eval, AF

Line No	Program Element Number	Item	Act	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)	Se
1	0601102F	Defense Research Sciences	01	356,107				356,107	U
2	0601103F	University Research Initiatives	01	158,859				158,859	U
3	0601108F	High Energy Laser Research Initiatives	01	14,795				14,795	U
		Basic Research		529,761				529,761	
4	0602102F	Materials	02	128,851				128,851	U
5	0602201F	Aerospace Vehicle Technologies	02	147,724				147,724	U
6	0602202F	Human Effectiveness Applied Research	02	131,795				131,795	U
7	0602203F	Aerospace Propulsion	02	198,775				198,775	U
8	0602204F	Aerospace Sensors	02	202,912				202,912	U
9	0602212F	Defense Laboratories R&D Projects (10 U.S.C, Sec 2358)	02						U
10	0602298F	Science and Technology Management - Major Headquarters Activities	02	7,968				7,968	U
11	0602601F	Space Technology	02						U
12	0602602F	Conventional Munitions	02	142,772				142,772	U
13	0602605F	Directed Energy Technology	02	124,379				124,379	U
14	0602788F	Dominant Information Sciences and Methods	02	181,562				181,562	U
15	0602890F	High Energy Laser Research	02	44,221				44,221	U
16	1206601F	Space Technology	02	124,667				124,667	U
		Applied Research		1,435,626				1,435,626	

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 (Dollars in Thousands)

19 Feb 2019

Appropriation: 3600F Research, Development, Test & Eval, AF

Line No	Program Element Number	Item	Act	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted	Se c
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17	0603112F	Advanced Materials for Weapon Systems	03	34,694	47,426		47,426	U
18	0603199F	Sustainment Science and Technology (S&T)	03	20,724	15,150		15,150	U
19	0603203F	Advanced Aerospace Sensors	03	46,784	44,968		44,968	U
20	0603211F	Aerospace Technology Dev/Demo	03	103,123	126,002		126,002	U
21	0603216F	Aerospace Propulsion and Power Technology	03	122,217	148,418		148,418	U
22	0603270F	Electronic Combat Technology	03	56,238	55,054		55,054	U
23	0603401F	Advanced Spacecraft Technology	03	94,946	70,734		70,734	U
24	0603444F	Maui Space Surveillance System (MSSS)	03	9,755	10,674		10,674	U
25	0603456F	Human Effectiveness Advanced Technology Development	03	30,153	36,420		36,420	U
26	0603601F	Conventional Weapons Technology	03	157,676	204,756		204,756	U
27	0603605F	Advanced Weapons Technology	03	42,322	43,368		43,368	U
28	0603680F	Manufacturing Technology Program	03	63,224	65,760		65,760	U
29	0603788F	Battlespace Knowledge Development and Demonstration	03	45,481	60,017		60,017	U
30	0303467F	SENSR Spectrum Pipeline SRF	03	2,188				U
		Advanced Technology Development		829,525	928,747		928,747	
31	0603260F	Intelligence Advanced Development	04	7,652	5,568		5,568	U
32	0603742F	Combat Identification Technology	04	23,578	18,194		18,194	U

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Appropriation: 3600F Research, Development, Test & Eval, AF

Line No	Program Element Number	Item	Act	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)	Se
17	0603112F	Advanced Materials for Weapon Systems	03	36,586				36,586	U
18	0603199F	Sustainment Science and Technology (S&T)	03	16,249				16,249	U
19	0603203F	Advanced Aerospace Sensors	03	38,292				38,292	U
20	0603211F	Aerospace Technology Dev/Demo	03	102,949				102,949	U
21	0603216F	Aerospace Propulsion and Power Technology	03	113,973				113,973	U
22	0603270F	Electronic Combat Technology	03	48,408				48,408	U
23	0603401F	Advanced Spacecraft Technology	03	70,525				70,525	U
24	0603444F	Maui Space Surveillance System (MSSS)	03	11,878				11,878	U
25	0603456F	Human Effectiveness Advanced Technology Development	03	37,542				37,542	U
26	0603601F	Conventional Weapons Technology	03	225,817				225,817	U
27	0603605F	Advanced Weapons Technology	03	37,404				37,404	U
28	0603680F	Manufacturing Technology Program	03	43,116				43,116	U
29	0603788F	Battlespace Knowledge Development and Demonstration	03	56,414				56,414	U
30	0303467F	SENSR Spectrum Pipeline SRF	03						U
		Advanced Technology Development		839,153				839,153	
31	0603260F	Intelligence Advanced Development	04	5,672				5,672	U
32	0603742F	Combat Identification Technology	04	27,085				27,085	U

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Appropriation: 3600F Research, Development, Test & Eval, AF

Line No	Program Element Number	Item	Act	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted	Se c
--	-----	----	---	-----	-----	-----	-----	-
33	0603790F	NATO Research and Development	04	3,710	2,305		2,305	U
34	0603851F	Intercontinental Ballistic Missile - Dem/Val	04	27,424	32,356		32,356	U
35	0603859F	Pollution Prevention - Dem/Val	04	2	200		200	U
36	0604002F	Air Force Weather Services Research	04					U
37	0604004F	Advanced Engine Development	04		720,355		720,355	U
38	0604015F	Long Range Strike - Bomber	04	1,914,611	2,279,196		2,279,196	U
39	0604032F	Directed Energy Prototyping	04		50,000		50,000	U
40	0604033F	Hypersonics Prototyping	04		508,858		508,858	U
41	0604201F	PNT Resiliency, Mods, and Improvements	04	63,302	81,271		81,271	U
42	0604257F	Advanced Technology and Sensors	04	78,122	34,585		34,585	U
43	0604288F	National Airborne Ops Center (NAOC) Recap	04	6,141	7,440		7,440	U
44	0604317F	Technology Transfer	04	17,644	16,924		16,924	U
45	0604327F	Hard and Deeply Buried Target Defeat System (HDBTDS) Program	04	39,682	36,701		36,701	U
46	0604414F	Cyber Resiliency of Weapon Systems-ACS	04	41,055	62,618		62,618	U
47	0604776F	Deployment & Distribution Enterprise R&D	04	25,597	27,964		27,964	U
48	0604858F	Tech Transition Program	04	1,079,458	167,277		167,277	U
49	0605230F	Ground Based Strategic Deterrent	04	221,536	414,441		414,441	U

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Line No	Program Element Number	Item	Act	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)	Se
33	0603790F	NATO Research and Development	04	4,955				4,955	U
34	0603851F	Intercontinental Ballistic Missile - Dem/Val	04	44,109				44,109	U
35	0603859F	Pollution Prevention - Dem/Val	04						U
36	0604002F	Air Force Weather Services Research	04	772				772	U
37	0604004F	Advanced Engine Development	04	878,442				878,442	U
38	0604015F	Long Range Strike - Bomber	04	3,003,899				3,003,899	U
39	0604032F	Directed Energy Prototyping	04	10,000				10,000	U
40	0604033F	Hypersonics Prototyping	04	576,000				576,000	U
41	0604201F	PNT Resiliency, Mods, and Improvements	04	92,600				92,600	U
42	0604257F	Advanced Technology and Sensors	04	23,145				23,145	U
43	0604288F	National Airborne Ops Center (NAOC) Recap	04	16,669				16,669	U
44	0604317F	Technology Transfer	04	23,614				23,614	U
45	0604327F	Hard and Deeply Buried Target Defeat System (HDBTDS) Program	04	113,121				113,121	U
46	0604414F	Cyber Resiliency of Weapon Systems-ACS	04	56,325				56,325	U
47	0604776F	Deployment & Distribution Enterprise R&D	04	28,034				28,034	U
48	0604858F	Tech Transition Program	04	128,476		26,450	26,450	154,926	U
49	0605230F	Ground Based Strategic Deterrent	04	570,373				570,373	U

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Appropriation: 3600F Research, Development, Test & Eval, AF

Line No	Program Element Number	Item	Act	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted	Se
50	0207100F	Light Attack Armed Reconnaissance (LAAR) Squadrons	04					U
51	0207110F	Next Generation Air Dominance	04	283,964	429,610		429,610	U
52	0207455F	Three Dimensional Long-Range Radar (3DELRR)	04	12,122	24,856		24,856	U
53	0208099F	Unified Platform (UP)	04		29,800		29,800	U
54	0305236F	Common Data Link Executive Agent (CDL EA)	04	40,838	41,880		41,880	U
55	0305251F	Cyberspace Operations Forces and Force Support	04					U
56	0305601F	Mission Partner Environments	04		10,074		10,074	U
57	0306250F	Cyber Operations Technology Development	04	278,521	246,502		246,502	U
58	0306415F	Enabled Cyber Activities	04	16,687	16,325		16,325	U
59	0408011F	Special Tactics / Combat Control	04	4,266				U
60	0901410F	Contracting Information Technology System	04	18,973	17,577		17,577	U
61	1203164F	NAVSTAR Global Positioning System (User Equipment) (SPACE)	04	321,186	252,834		252,834	U
62	1203710F	EO/IR Weather Systems	04	8,000	7,940		7,940	U
63	1206422F	Weather System Follow-on	04	98,396	138,052		138,052	U
64	1206425F	Space Situation Awareness Systems	04	43,290	33,469		33,469	U
65	1206427F	Space Systems Prototype Transitions (SSPT)	04					U

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50	0207100F	Light Attack Armed Reconnaissance (LAAR) Squadrons	04	35,000				35,000	U
51	0207110F	Next Generation Air Dominance	04	1,000,000				1,000,000	U
52	0207455F	Three Dimensional Long-Range Radar (3DELRR)	04	37,290				37,290	U
53	0208099F	Unified Platform (UP)	04	10,000				10,000	U
54	0305236F	Common Data Link Executive Agent (CDL EA)	04	36,910				36,910	U
55	0305251F	Cyberspace Operations Forces and Force Support	04	35,000				35,000	U
56	0305601F	Mission Partner Environments	04	8,550				8,550	U
57	0306250F	Cyber Operations Technology Development	04	198,864				198,864	U
58	0306415F	Enabled Cyber Activities	04	16,632				16,632	U
59	0408011F	Special Tactics / Combat Control	04						U
60	0901410F	Contracting Information Technology System	04	20,830				20,830	U
61	1203164F	NAVSTAR Global Positioning System (User Equipment) (SPACE)	04	329,948				329,948	U
62	1203710F	EO/IR Weather Systems	04	101,222				101,222	U
63	1206422F	Weather System Follow-on	04	225,660				225,660	U
64	1206425F	Space Situation Awareness Systems	04	29,776				29,776	U
65	1206427F	Space Systems Prototype Transitions (SSPT)	04	142,045				142,045	U

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66	1206434F	Midterm Polar MILSATCOM System	04	60,123	383,113		383,113	U
67	1206438F	Space Control Technology	04	44,139	90,546	1,100	91,646	U
68	1206730F	Space Security and Defense Program	04	41,385	45,542		45,542	U
69	1206760F	Protected Tactical Enterprise Service (PTES)	04	17,552	46,419		46,419	U
70	1206761F	Protected Tactical Service (PTS)	04	23,404	29,626		29,626	U
71	1206855F	Evolved Strategic SATCOM (ESS)	04	15,473	29,229		29,229	U
72	1206857F	Space Rapid Capabilities Office	04	84,235	286,050	12,395	298,445	U
		Advanced Component Development & Prototypes		4,962,068	6,625,697	13,495	6,639,192	
73	0604200F	Future Advanced Weapon Analysis & Programs	05	5,108	39,602		39,602	U
74	0604201F	PNT Resiliency, Mods, and Improvements	05	97,943	46,731		46,731	U
75	0604222F	Nuclear Weapons Support	05	2,910	4,468		4,468	U
76	0604270F	Electronic Warfare Development	05	2,159	1,909		1,909	U
77	0604281F	Tactical Data Networks Enterprise	05	42,128	270,015		270,015	U
78	0604287F	Physical Security Equipment	05	39,639	14,421		14,421	U
79	0604329F	Small Diameter Bomb (SDB) - EMD	05	37,667	78,091		78,091	U
80	0604429F	Airborne Electronic Attack	05	4,910	6,153		6,153	U
81	0604602F	Armament/Ordnance Development	05	16,765	49,590		49,590	U
82	0604604F	Submunitions	05	2,697	2,990		2,990	U
83	0604617F	Agile Combat Support	05	36,351	23,489		23,489	U

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66	1206434F	Midterm Polar MILSATCOM System	04						U
67	1206438F	Space Control Technology	04	64,231				64,231	U
68	1206730F	Space Security and Defense Program	04	56,385				56,385	U
69	1206760F	Protected Tactical Enterprise Service (PTES)	04	105,003				105,003	U
70	1206761F	Protected Tactical Service (PTS)	04	173,694				173,694	U
71	1206855F	Evolved Strategic SATCOM (ESS)	04	172,206				172,206	U
72	1206857F	Space Rapid Capabilities Office	04	33,742		17,885	17,885	51,627	U
		Advanced Component Development & Prototypes		8,436,279		44,335	44,335	8,480,614	
73	0604200F	Future Advanced Weapon Analysis & Programs	05	246,200				246,200	U
74	0604201F	PNT Resiliency, Mods, and Improvements	05	67,782				67,782	U
75	0604222F	Nuclear Weapons Support	05	4,406				4,406	U
76	0604270F	Electronic Warfare Development	05	2,066				2,066	U
77	0604281F	Tactical Data Networks Enterprise	05	229,631				229,631	U
78	0604287F	Physical Security Equipment	05	9,700				9,700	U
79	0604329F	Small Diameter Bomb (SDB) - EMD	05	31,241				31,241	U
80	0604429F	Airborne Electronic Attack	05	2				2	U
81	0604602F	Armament/Ordnance Development	05	28,043				28,043	U
82	0604604F	Submunitions	05	3,045				3,045	U
83	0604617F	Agile Combat Support	05	19,944				19,944	U

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84	0604706F	Life Support Systems	05	10,342	8,919		8,919	U
85	0604735F	Combat Training Ranges	05	75,981	43,895		43,895	U
86	0604800F	F-35 - EMD	05	282,126	69,001		69,001	U
87	0604932F	Long Range Standoff Weapon	05	437,521	664,920		664,920	U
88	0604933F	ICBM Fuze Modernization	05	166,571	167,659		167,659	U
89	0605030F	Joint Tactical Network Center (JTNC)	05	404				U
90	0605031F	Joint Tactical Network (JTN)	05	1,331				U
91	0605056F	Open Architecture Management	05					U
92	0605213F	F-22 Modernization Increment 3.2B	05	10,482				U
93	0605221F	KC-46	05	75,598	80,170		80,170	U
94	0605223F	Advanced Pilot Training	05	82,628	245,465		245,465	U
95	0605229F	Combat Rescue Helicopter	05	342,030	445,652		445,652	U
96	0605458F	Air & Space Ops Center 10.2 RDT&E	05	4,666				U
97	0605830F	Acq Workforce- Global Battle Mgmt	05		3,617		3,617	U
98	0605931F	B-2 Defensive Management System	05	148,946	253,258		253,258	U
99	0101125F	Nuclear Weapons Modernization	05	81,631	81,592		81,592	U
100	0101213F	Minuteman Squadrons	05					U
101	0207171F	F-15 EPAWSS	05	202,167	137,095		137,095	U
102	0207328F	Stand In Attack Weapon	05	3,288	14,975		14,975	U
103	0207701F	Full Combat Mission Training	05	8,427	1,015		1,015	U

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84	0604706F	Life Support Systems	05	8,624				8,624	U
85	0604735F	Combat Training Ranges	05	37,365				37,365	U
86	0604800F	F-35 - EMD	05	7,628				7,628	U
87	0604932F	Long Range Standoff Weapon	05	712,539				712,539	U
88	0604933F	ICBM Fuze Modernization	05	161,199				161,199	U
89	0605030F	Joint Tactical Network Center (JTNC)	05	2,414				2,414	U
90	0605031F	Joint Tactical Network (JTN)	05						U
91	0605056F	Open Architecture Management	05	30,000				30,000	U
92	0605213F	F-22 Modernization Increment 3.2B	05						U
93	0605221F	KC-46	05	59,561				59,561	U
94	0605223F	Advanced Pilot Training	05	348,473				348,473	U
95	0605229F	Combat Rescue Helicopter	05	247,047				247,047	U
96	0605458F	Air & Space Ops Center 10.2 RDT&E	05						U
97	0605830F	Acq Workforce- Global Battle Mgmt	05						U
98	0605931F	B-2 Defensive Management System	05	294,400				294,400	U
99	0101125F	Nuclear Weapons Modernization	05	27,564				27,564	U
100	0101213F	Minuteman Squadrons	05	1				1	U
101	0207171F	F-15 EPAWSS	05	47,322				47,322	U
102	0207328F	Stand In Attack Weapon	05	162,840				162,840	U
103	0207701F	Full Combat Mission Training	05	9,797				9,797	U

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104	0303267F	Auctioned Spectrum Relocation Fund	05	60,546				U
105	0307581F	JSTARS Recap	05	390,713				U
106	0401310F	C-32 Executive Transport Recapitalization	05	2,918	7,943		7,943	U
107	0401319F	VC-25B	05	418,500	657,932		657,932	U
108	0701212F	Automated Test Systems	05	17,850	13,653		13,653	U
109	1203176F	Combat Survivor Evader Locator	05	24,099	939		939	U
110	1203269F	GPS III Follow-On (GPS IIIF)	05		426,889		426,889	U
111	1203940F	Space Situation Awareness Operations	05	9,684	46,015		46,015	U
112	1206421F	Counterspace Systems	05	64,208	20,242		20,242	U
113	1206422F	Weather System Follow-on	05					U
114	1206425F	Space Situation Awareness Systems	05	47,580	134,464		134,464	U
115	1206426F	Space Fence	05	34,022	19,425		19,425	U
116	1206431F	Advanced EHF MILSATCOM (SPACE)	05	134,775	144,753		144,753	U
117	1206432F	Polar MILSATCOM (SPACE)	05	32,536	26,380		26,380	U
118	1206433F	Wideband Global SATCOM (SPACE)	05	6,535	3,970		3,970	U
119	1206441F	Space Based Infrared System (SBIRS) High EMD	05	119,585	60,565		60,565	U
120	1206442F	Next Generation OPIR	05	439,497	643,126		643,126	U
121	1206445F	Commercial SATCOM (COMSATCOM) Integration	05		49,500		49,500	U

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104	0303267F	Auctioned Spectrum Relocation Fund	05						U
105	0307581F	JSTARS Recap	05						U
106	0401310F	C-32 Executive Transport Recapitalization	05	9,930				9,930	U
107	0401319F	VC-25B	05	757,923				757,923	U
108	0701212F	Automated Test Systems	05	2,787				2,787	U
109	1203176F	Combat Survivor Evader Locator	05	2,000				2,000	U
110	1203269F	GPS III Follow-On (GPS IIIF)	05	462,875				462,875	U
111	1203940F	Space Situation Awareness Operations	05	76,829				76,829	U
112	1206421F	Counterspace Systems	05	29,037				29,037	U
113	1206422F	Weather System Follow-on	05	2,237				2,237	U
114	1206425F	Space Situation Awareness Systems	05	412,894				412,894	U
115	1206426F	Space Fence	05						U
116	1206431F	Advanced EHF MILSATCOM (SPACE)	05	117,290				117,290	U
117	1206432F	Polar MILSATCOM (SPACE)	05	427,400				427,400	U
118	1206433F	Wideband Global SATCOM (SPACE)	05	1,920				1,920	U
119	1206441F	Space Based Infrared System (SBIRS) High EMD	05	1				1	U
120	1206442F	Next Generation OPIR	05	1,395,278				1,395,278	U
121	1206445F	Commercial SATCOM (COMSATCOM) Integration	05						U

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122	1206853F	National Security Space Launch Program (SPACE) - EMD	05	381,877	443,035		443,035	U
		System Development & Demonstration		4,407,341	5,453,523		5,453,523	
123	0604256F	Threat Simulator Development	06	34,777	34,206		34,206	U
124	0604759F	Major T&E Investment	06	111,138	216,844		216,844	U
125	0605101F	RAND Project Air Force	06	33,089	34,614		34,614	U
126	0605502F	Small Business Innovation Research	06	663,657				U
127	0605712F	Initial Operational Test & Evaluation	06	15,523	18,043		18,043	U
128	0605807F	Test and Evaluation Support	06	735,688	692,784		692,784	U
129	0605826F	Acq Workforce- Global Power	06	216,144	227,824		227,824	U
130	0605827F	Acq Workforce- Global Vig & Combat Sys	06	225,854	256,617		256,617	U
131	0605828F	Acq Workforce- Global Reach	06	138,491	149,586		149,586	U
132	0605829F	Acq Workforce- Cyber, Network, & Bus Sys	06	205,643	226,257		226,257	U
133	0605830F	Acq Workforce- Global Battle Mgmt	06	146,852	165,438		165,438	U
134	0605831F	Acq Workforce- Capability Integration	06	221,676	220,320		220,320	U
135	0605832F	Acq Workforce- Advanced Prgm Technology	06	27,997	37,399		37,399	U
136	0605833F	Acq Workforce- Nuclear Systems	06	124,111	122,481		122,481	U
137	0605898F	Management HQ - R&D	06	9,394	10,364		10,364	U

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122	1206853F	National Security Space Launch Program (SPACE) - EMD	05	432,009				432,009	U
		System Development & Demonstration		6,929,244				6,929,244	
123	0604256F	Threat Simulator Development	06	59,693				59,693	U
124	0604759F	Major T&E Investment	06	181,663				181,663	U
125	0605101F	RAND Project Air Force	06	35,258				35,258	U
126	0605502F	Small Business Innovation Research	06						U
127	0605712F	Initial Operational Test & Evaluation	06	13,793				13,793	U
128	0605807F	Test and Evaluation Support	06	717,895				717,895	U
129	0605826F	Acq Workforce- Global Power	06	258,667				258,667	U
130	0605827F	Acq Workforce- Global Vig & Combat Sys	06	251,992				251,992	U
131	0605828F	Acq Workforce- Global Reach	06	149,191				149,191	U
132	0605829F	Acq Workforce- Cyber, Network, & Bus Sys	06	235,360				235,360	U
133	0605830F	Acq Workforce- Global Battle Mgmt	06	160,196				160,196	U
134	0605831F	Acq Workforce- Capability Integration	06	220,255				220,255	U
135	0605832F	Acq Workforce- Advanced Prgm Technology	06	42,392				42,392	U
136	0605833F	Acq Workforce- Nuclear Systems	06	133,231				133,231	U
137	0605898F	Management HQ - R&D	06	5,590				5,590	U

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138	0605976F	Facilities Restoration and Modernization - Test and Evaluation Support	06	135,507	187,216		187,216	U
139	0605978F	Facilities Sustainment - Test and Evaluation Support	06	28,720	28,888		28,888	U
140	0606017F	Requirements Analysis and Maturation	06	106,646	48,070		48,070	U
141	0606398F	Management HQ - T&E	06					U
142	0308602F	ENTEPRISE INFORMATION SERVICES (EIS)	06	18,980	20,435		20,435	U
143	0702806F	Acquisition and Management Support	06	14,706	12,367		12,367	U
144	0804731F	General Skill Training	06	457	448		448	U
145	0909999F	Financing for Cancelled Account Adjustments	06	391				U
146	1001004F	International Activities	06	4,418	3,998		3,998	U
147	1206116F	Space Test and Training Range Development	06	24,886	23,157		23,157	U
148	1206392F	Space and Missile Center (SMC) Civilian Workforce	06	175,247	169,912		169,912	U
149	1206398F	Space & Missile Systems Center - MHA	06	8,681	10,508		10,508	U
150	1206860F	Rocket Systems Launch Program (SPACE)	06	33,023	19,721		19,721	U
151	1206864F	Space Test Program (STP)	06	29,016	25,620		25,620	U
		Management Support		3,490,712	2,963,117		2,963,117	
152	0604003F	Advanced Battle Management System (ABMS)	07		27,883		27,883	U

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138	0605976F	Facilities Restoration and Modernization - Test and Evaluation Support	06	88,445				88,445	U
139	0605978F	Facilities Sustainment - Test and Evaluation Support	06	29,424				29,424	U
140	0606017F	Requirements Analysis and Maturation	06	62,715				62,715	U
141	0606398F	Management HQ - T&E	06	5,013				5,013	U
142	0308602F	ENTEPRISE INFORMATION SERVICES (EIS)	06	17,128				17,128	U
143	0702806F	Acquisition and Management Support	06	5,913				5,913	U
144	0804731F	General Skill Training	06	1,475				1,475	U
145	0909999F	Financing for Cancelled Account Adjustments	06						U
146	1001004F	International Activities	06	4,071				4,071	U
147	1206116F	Space Test and Training Range Development	06	19,942				19,942	U
148	1206392F	Space and Missile Center (SMC) Civilian Workforce	06	167,810				167,810	U
149	1206398F	Space & Missile Systems Center - MHA	06	10,170				10,170	U
150	1206860F	Rocket Systems Launch Program (SPACE)	06	13,192				13,192	U
151	1206864F	Space Test Program (STP)	06	26,097				26,097	U
		Management Support		2,916,571				2,916,571	
152	0604003F	Advanced Battle Management System (ABMS)	07	35,611				35,611	U

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Line No	Program Element Number	Item	Act	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted	Se
153	0604222F	Nuclear Weapons Support	07	26,672				U
154	0604233F	Specialized Undergraduate Flight Training	07	6,269	11,344		11,344	U
155	0604445F	Wide Area Surveillance	07	37,750				U
156	0604776F	Deployment & Distribution Enterprise R&D	07					U
157	0604840F	F-35 C2D2	07					U
158	0605018F	AF Integrated Personnel and Pay System (AF-IPPS)	07	17,298	41,058		41,058	U
159	0605024F	Anti-Tamper Technology Executive Agency	07	37,304	32,770		32,770	U
160	0605117F	Foreign Materiel Acquisition and Exploitation	07	66,653	68,368		68,368	U
161	0605278F	HC/MC-130 Recap RDT&E	07	30,784	16,174		16,174	U
162	0606018F	NC3 Integration	07	12,382	19,312		19,312	U
163	0606942F	Assessments and Evaluations Cyber Vulnerabilities	07		87,800		87,800	U
164	0101113F	B-52 Squadrons	07	107,936	291,264	34,000	325,264	U
165	0101122F	Air-Launched Cruise Missile (ALCM)	07	446	5,955		5,955	U
166	0101126F	B-1B Squadrons	07	60,367	60,295		60,295	U
167	0101127F	B-2 Squadrons	07	89,781	105,508		105,508	U
168	0101213F	Minuteman Squadrons	07	204,208	154,733		154,733	U

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Line No	Program Element Number	Item	Act	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)	Se
153	0604222F	Nuclear Weapons Support	07						U
154	0604233F	Specialized Undergraduate Flight Training	07	2,584				2,584	U
155	0604445F	Wide Area Surveillance	07						U
156	0604776F	Deployment & Distribution Enterprise R&D	07	903				903	U
157	0604840F	F-35 C2D2	07	694,455				694,455	U
158	0605018F	AF Integrated Personnel and Pay System (AF-IPPS)	07	40,567				40,567	U
159	0605024F	Anti-Tamper Technology Executive Agency	07	47,193				47,193	U
160	0605117F	Foreign Materiel Acquisition and Exploitation	07	70,083				70,083	U
161	0605278F	HC/MC-130 Recap RDT&E	07	17,218				17,218	U
162	0606018F	NC3 Integration	07	25,917				25,917	U
163	0606942F	Assessments and Evaluations Cyber Vulnerabilities	07						U
164	0101113F	B-52 Squadrons	07	325,974				325,974	U
165	0101122F	Air-Launched Cruise Missile (ALCM)	07	10,217				10,217	U
166	0101126F	B-1B Squadrons	07	1,000				1,000	U
167	0101127F	B-2 Squadrons	07	97,276				97,276	U
168	0101213F	Minuteman Squadrons	07	128,961				128,961	U

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169	0101313F	Integrated Strategic Planning and Analysis Network (ISPAN) - USSTRATCOM	07	24,898				U
170	0101316F	Worldwide Joint Strategic Communications	07	12,868	18,442		18,442	U
171	0101324F	Integrated Strategic Planning & Analysis Network	07	10,757	22,833		22,833	U
172	0101328F	ICBM Reentry Vehicles	07		14,167		14,167	U
174	0102110F	UH-1N Replacement Program	07	188,259	258,022		258,022	U
175	0102326F	Region/Sector Operation Control Center Modernization Program	07	3,766	6,112		6,112	U
176	0205219F	MQ-9 UAV	07	184,353	104,345	4,500	108,845	U
177	0205671F	Joint Counter RCIED Electronic Warfare	07			4,000	4,000	U
178	0207131F	A-10 Squadrons	07	17,459	26,738	1,000	27,738	U
179	0207133F	F-16 Squadrons	07	250,264	185,864		185,864	U
180	0207134F	F-15E Squadrons	07	308,218	203,183		203,183	U
181	0207136F	Manned Destructive Suppression	07	11,735	15,238		15,238	U
182	0207138F	F-22A Squadrons	07	584,004	584,743		584,743	U
183	0207142F	F-35 Squadrons	07	325,224	503,928		503,928	U
184	0207161F	Tactical AIM Missiles	07	36,303	37,230		37,230	U
185	0207163F	Advanced Medium Range Air-to-Air Missile (AMRAAM)	07	51,374	57,293		57,293	U
186	0207227F	Combat Rescue - Pararescue	07	685	647		647	U

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169	0101313F	Integrated Strategic Planning and Analysis Network (ISPAN) - USSTRATCOM	07						U
170	0101316F	Worldwide Joint Strategic Communications	07	18,177				18,177	U
171	0101324F	Integrated Strategic Planning & Analysis Network	07	24,261				24,261	U
172	0101328F	ICBM Reentry Vehicles	07	75,571				75,571	U
174	0102110F	UH-1N Replacement Program	07	170,975				170,975	U
175	0102326F	Region/Sector Operation Control Center Modernization Program	07						U
176	0205219F	MQ-9 UAV	07	154,996				154,996	U
177	0205671F	Joint Counter RCIED Electronic Warfare	07			4,000	4,000	4,000	U
178	0207131F	A-10 Squadrons	07	36,816				36,816	U
179	0207133F	F-16 Squadrons	07	193,013				193,013	U
180	0207134F	F-15E Squadrons	07	336,079				336,079	U
181	0207136F	Manned Destructive Suppression	07	15,521				15,521	U
182	0207138F	F-22A Squadrons	07	496,298				496,298	U
183	0207142F	F-35 Squadrons	07	99,943				99,943	U
184	0207161F	Tactical AIM Missiles	07	10,314				10,314	U
185	0207163F	Advanced Medium Range Air-to-Air Missile (AMRAAM)	07	55,384				55,384	U
186	0207227F	Combat Rescue - Pararescue	07	281				281	U

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187	0207247F	AF TENCAP	07					U
188	0207249F	Precision Attack Systems Procurement	07	1,651	14,891		14,891	U
189	0207253F	Compass Call	07	34,240	43,901		43,901	U
190	0207268F	Aircraft Engine Component Improvement Program	07	105,664	121,203		121,203	U
191	0207325F	Joint Air-to-Surface Standoff Missile (JASSM)	07	29,436	42,472		42,472	U
192	0207410F	Air & Space Operations Center (AOC)	07	86,456	104,954		104,954	U
193	0207412F	Control and Reporting Center (CRC)	07	2,374	6,413		6,413	U
194	0207417F	Airborne Warning and Control System (AWACS)	07	118,702	112,280		112,280	U
195	0207418F	Tactical Airborne Control Systems	07	3,522	2,659		2,659	U
197	0207431F	Combat Air Intelligence System Activities	07	15,821	10,316		10,316	U
198	0207444F	Tactical Air Control Party-Mod	07	10,623	6,149		6,149	U
199	0207448F	C2ISR Tactical Data Link	07	1,754	538		538	U
200	0207452F	DCAPES	07	12,423	13,248		13,248	U
201	0207573F	National Technical Nuclear Forensics	07	2,307	1,788		1,788	U
202	0207590F	Seek Eagle	07	25,304	24,699		24,699	U
203	0207601F	USAF Modeling and Simulation	07	9,803	17,078		17,078	U
204	0207605F	Wargaming and Simulation Centers	07	12,369	6,141		6,141	U
205	0207610F	Battlefield Abn Comm Node (BACN)	07			42,349	42,349	U

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187	0207247F	AF TENCAP	07	21,365				21,365	U
188	0207249F	Precision Attack Systems Procurement	07	10,696				10,696	U
189	0207253F	Compass Call	07	15,888				15,888	U
190	0207268F	Aircraft Engine Component Improvement Program	07	112,505				112,505	U
191	0207325F	Joint Air-to-Surface Standoff Missile (JASSM)	07	78,498				78,498	U
192	0207410F	Air & Space Operations Center (AOC)	07	114,864				114,864	U
193	0207412F	Control and Reporting Center (CRC)	07	8,109				8,109	U
194	0207417F	Airborne Warning and Control System (AWACS)	07	67,996				67,996	U
195	0207418F	Tactical Airborne Control Systems	07	2,462				2,462	U
197	0207431F	Combat Air Intelligence System Activities	07	13,668				13,668	U
198	0207444F	Tactical Air Control Party-Mod	07	6,217				6,217	U
199	0207448F	C2ISR Tactical Data Link	07						U
200	0207452F	DCAPES	07	19,910				19,910	U
201	0207573F	National Technical Nuclear Forensics	07	1,788				1,788	U
202	0207590F	Seek Eagle	07	28,237				28,237	U
203	0207601F	USAF Modeling and Simulation	07	15,725				15,725	U
204	0207605F	Wargaming and Simulation Centers	07	4,316				4,316	U
205	0207610F	Battlefield Abn Comm Node (BACN)	07	26,946				26,946	U

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Line No	Program Element Number	Item	Act	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted	Se
206	0207697F	Distributed Training and Exercises	07	4,046	3,825		3,825	U
207	0208006F	Mission Planning Systems	07	82,054	63,074		63,074	U
208	0208007F	Tactical Deception	07	3,623	6,949		6,949	U
209	0208064F	OPERATIONAL HQ - CYBER	07					U
210	0208087F	Distributed Cyber Warfare Operations	07	38,241	40,168		40,168	U
211	0208088F	AF Defensive Cyberspace Operations	07	19,628	38,387		38,387	U
212	0208097F	Joint Cyber Command and Control (JCC2)	07		13,000		13,000	U
213	0208099F	Unified Platform (UP)	07		26,559		26,559	U
217	0208288F	Intel Data Applications	07			1,200	1,200	U
218	0301017F	Global Sensor Integrated on Network (GSIN)	07	3,439	3,579		3,579	U
219	0301025F	GeoBase	07					U
220	0301112F	Nuclear Planning and Execution System (NPES)	07	5,056	29,620		29,620	U
226	0301401F	Air Force Space and Cyber Non-Traditional ISR for Battlespace Awareness	07	3,721	6,633		6,633	U
227	0302015F	E-4B National Airborne Operations Center (NAOC)	07	37,481	57,758		57,758	U
228	0303131F	Minimum Essential Emergency Communications Network (MEECN)	07	34,466	64,543		64,543	U
229	0303133F	High Frequency Radio Systems	07		51,612		51,612	U
230	0303140F	Information Systems Security Program	07	41,067	33,979		33,979	U

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Line No	Program Element Number	Item	Act	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)	Se
206	0207697F	Distributed Training and Exercises	07	4,303				4,303	U
207	0208006F	Mission Planning Systems	07	71,465				71,465	U
208	0208007F	Tactical Deception	07	7,446				7,446	U
209	0208064F	OPERATIONAL HQ - CYBER	07	7,602				7,602	U
210	0208087F	Distributed Cyber Warfare Operations	07	35,178				35,178	U
211	0208088F	AF Defensive Cyberspace Operations	07	16,609				16,609	U
212	0208097F	Joint Cyber Command and Control (JCC2)	07	11,603				11,603	U
213	0208099F	Unified Platform (UP)	07	84,702				84,702	U
217	0208288F	Intel Data Applications	07			1,200	1,200	1,200	U
218	0301017F	Global Sensor Integrated on Network (GSIN)	07						U
219	0301025F	GeoBase	07	2,723				2,723	U
220	0301112F	Nuclear Planning and Execution System (NPES)	07	44,190				44,190	U
226	0301401F	Air Force Space and Cyber Non-Traditional ISR for Battlespace Awareness	07	3,575				3,575	U
227	0302015F	E-4B National Airborne Operations Center (NAOC)	07	70,173				70,173	U
228	0303131F	Minimum Essential Emergency Communications Network (MEECN)	07	13,543				13,543	U
229	0303133F	High Frequency Radio Systems	07	15,881				15,881	U
230	0303140F	Information Systems Security Program	07	27,726				27,726	U

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231	0303141F	Global Combat Support System	07	101				U
232	0303142F	Global Force Management - Data Initiative	07	1,944	2,170		2,170	U
234	0304115F	Multi Domain Command and Control (MDC2)	07					U
235	0304260F	Airborne SIGINT Enterprise	07	116,186	109,873		109,873	U
236	0304310F	Commercial Economic Analysis	07	3,544	3,472		3,472	U
239	0305015F	C2 Air Operations Suite - C2 Info Services	07		8,608		8,608	U
240	0305020F	CCMD Intelligence Information Technology	07	1,542	1,586		1,586	U
241	0305022F	ISR Modernization & Automation Dvmt (IMAD)	07					U
242	0305099F	Global Air Traffic Management (GATM)	07	4,887	4,106		4,106	U
243	0305111F	Weather Service	07	35,689	31,615	3,000	34,615	U
244	0305114F	Air Traffic Control, Approach, and Landing System (ATCALs)	07	5,791	13,271		13,271	U
245	0305116F	Aerial Targets	07	20,944	6,683		6,683	U
248	0305128F	Security and Investigative Activities	07	400	418		418	U
249	0305145F	Arms Control Implementation	07		21,374		21,374	U
250	0305146F	Defense Joint Counterintelligence Activities	07	4,520	3,845		3,845	U
252	0305179F	Integrated Broadcast Service (IBS)	07					U

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Line No	Program Element Number	Item	Act	FY 2020 Base	FY 2020 OCO for Base Requirements	FY 2020 OCO for Direct War and Enduring Costs	FY 2020 Total OCO	FY 2020 Total (Base + OCO)	See
231	0303141F	Global Combat Support System	07						U
232	0303142F	Global Force Management - Data Initiative	07	2,210				2,210	U
234	0304115F	Multi Domain Command and Control (MDC2)	07	150,880				150,880	U
235	0304260F	Airborne SIGINT Enterprise	07	102,667				102,667	U
236	0304310F	Commercial Economic Analysis	07	3,431				3,431	U
239	0305015F	C2 Air Operations Suite - C2 Info Services	07	9,313				9,313	U
240	0305020F	CCMD Intelligence Information Technology	07	1,121				1,121	U
241	0305022F	ISR Modernization & Automation Dvmt (IMAD)	07	19,000				19,000	U
242	0305099F	Global Air Traffic Management (GATM)	07	4,544				4,544	U
243	0305111F	Weather Service	07	25,461				25,461	U
244	0305114F	Air Traffic Control, Approach, and Landing System (ATCALs)	07	5,651				5,651	U
245	0305116F	Aerial Targets	07	7,448				7,448	U
248	0305128F	Security and Investigative Activities	07	425				425	U
249	0305145F	Arms Control Implementation	07	54,546				54,546	U
250	0305146F	Defense Joint Counterintelligence Activities	07	6,858				6,858	U
252	0305179F	Integrated Broadcast Service (IBS)	07	8,728				8,728	U

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253	0305202F	Dragon U-2	07	34,486	65,518	22,100	87,618	U
254	0305205F	Endurance Unmanned Aerial Vehicles	07	40,000	15,000		15,000	U
255	0305206F	Airborne Reconnaissance Systems	07	19,450	195,334		195,334	U
256	0305207F	Manned Reconnaissance Systems	07	14,297	14,223		14,223	U
257	0305208F	Distributed Common Ground/Surface Systems	07	38,064	24,554	29,500	54,054	U
258	0305220F	RQ-4 UAV	07	222,693	221,690		221,690	U
259	0305221F	Network-Centric Collaborative Targeting	07	14,837	14,288		14,288	U
260	0305238F	NATO AGS	07	44,729	51,527		51,527	U
261	0305240F	Support to DCGS Enterprise	07	26,349	26,579		26,579	U
262	0305600F	International Intelligence Technology and Architectures	07	9,491	8,464		8,464	U
263	0305881F	Rapid Cyber Acquisition	07	4,720	4,303		4,303	U
264	0305984F	Personnel Recovery Command & Ctrl (PRC2)	07	2,364	2,466		2,466	U
265	0307577F	Intelligence Mission Data (IMD)	07	8,684	4,117		4,117	U
266	0401115F	C-130 Airlift Squadron	07	10,219	105,988		105,988	U
267	0401119F	C-5 Airlift Squadrons (IF)	07	11,433	25,071		25,071	U
268	0401130F	C-17 Aircraft (IF)	07	21,701	48,299		48,299	U
269	0401132F	C-130J Program	07	24,908	15,409		15,409	U
270	0401134F	Large Aircraft IR Countermeasures (LAIRCM)	07	5,095	4,334		4,334	U

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253	0305202F	Dragon U-2	07	38,939				38,939	U
254	0305205F	Endurance Unmanned Aerial Vehicles	07						U
255	0305206F	Airborne Reconnaissance Systems	07	122,909				122,909	U
256	0305207F	Manned Reconnaissance Systems	07	11,787				11,787	U
257	0305208F	Distributed Common Ground/Surface Systems	07	25,009				25,009	U
258	0305220F	RQ-4 UAV	07	191,733				191,733	U
259	0305221F	Network-Centric Collaborative Targeting	07	10,757				10,757	U
260	0305238F	NATO AGS	07	32,567				32,567	U
261	0305240F	Support to DCGS Enterprise	07	37,774				37,774	U
262	0305600F	International Intelligence Technology and Architectures	07	13,515				13,515	U
263	0305881F	Rapid Cyber Acquisition	07	4,383				4,383	U
264	0305984F	Personnel Recovery Command & Ctrl (PRC2)	07	2,133				2,133	U
265	0307577F	Intelligence Mission Data (IMD)	07	8,614				8,614	U
266	0401115F	C-130 Airlift Squadron	07	140,425				140,425	U
267	0401119F	C-5 Airlift Squadrons (IF)	07	10,223				10,223	U
268	0401130F	C-17 Aircraft (IF)	07	25,101				25,101	U
269	0401132F	C-130J Program	07	8,640				8,640	U
270	0401134F	Large Aircraft IR Countermeasures (LAIRCM)	07	5,424				5,424	U

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Line No	Program Element Number	Item	Act	FY 2018 (Base + OCO)	FY 2019 Base Enacted	FY 2019 OCO Enacted	FY 2019 Total Enacted	Se
271	0401218F	KC-135s	07	8,645	3,493		3,493	U
272	0401219F	KC-10s	07	9,181	6,569		6,569	U
273	0401314F	Operational Support Airlift	07	5,196	3,172		3,172	U
274	0401318F	CV-22	07	17,744	16,502		16,502	U
275	0401840F	AMC Command and Control System	07	3,394	1,688		1,688	U
276	0408011F	Special Tactics / Combat Control	07	7,726	2,433		2,433	U
277	0702207F	Depot Maintenance (Non-IF)	07	1,517	1,897		1,897	U
278	0708055F	Maintenance, Repair & Overhaul System	07	28,726	50,933		50,933	U
279	0708610F	Logistics Information Technology (LOGIT)	07	23,332	13,479		13,479	U
280	0708611F	Support Systems Development	07	11,362	4,497		4,497	U
281	0804743F	Other Flight Training	07	1,998	2,022		2,022	U
282	0808716F	Other Personnel Activities	07	103	108		108	U
283	0901202F	Joint Personnel Recovery Agency	07	1,933	2,023		2,023	U
284	0901218F	Civilian Compensation Program	07	2,905	3,561		3,561	U
285	0901220F	Personnel Administration	07	5,404	4,258		4,258	U
286	0901226F	Air Force Studies and Analysis Agency	07	1,506	1,418		1,418	U
287	0901538F	Financial Management Information Systems Development	07	87,802	93,418		93,418	U
288	0901554F	Defense Enterprise Acntng and Mgt Sys (DEAMS)	07					U

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271	0401218F	KC-135s	07						U
272	0401219F	KC-10s	07	20				20	U
273	0401314F	Operational Support Airlift	07						U
274	0401318F	CV-22	07	17,906				17,906	U
275	0401840F	AMC Command and Control System	07						U
276	0408011F	Special Tactics / Combat Control	07	3,629				3,629	U
277	0702207F	Depot Maintenance (Non-IF)	07	1,890				1,890	U
278	0708055F	Maintenance, Repair & Overhaul System	07	10,311				10,311	U
279	0708610F	Logistics Information Technology (LOGIT)	07	16,065				16,065	U
280	0708611F	Support Systems Development	07	539				539	U
281	0804743F	Other Flight Training	07	2,057				2,057	U
282	0808716F	Other Personnel Activities	07	10				10	U
283	0901202F	Joint Personnel Recovery Agency	07	2,060				2,060	U
284	0901218F	Civilian Compensation Program	07	3,809				3,809	U
285	0901220F	Personnel Administration	07	6,476				6,476	U
286	0901226F	Air Force Studies and Analysis Agency	07	1,443				1,443	U
287	0901538F	Financial Management Information Systems Development	07	9,323				9,323	U
288	0901554F	Defense Enterprise Acntng and Mgt Sys (DEAMS)	07	46,789				46,789	U

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289	1201017F	Global Sensor Integrated on Network (GSIN)	07					U
290	1201921F	Service Support to STRATCOM - Space Activities	07	13,769	14,161		14,161	U
291	1202140F	Service Support to SPACECOM Activities	07					U
292	1202247F	AF TENCAP	07	80,726	26,986	5,000	31,986	U
293	1203001F	Family of Advanced BLoS Terminals (FAB-T)	07	26,262	60,168		60,168	U
294	1203110F	Satellite Control Network (SPACE)	07	18,133	26,440		26,440	U
296	1203165F	NAVSTAR Global Positioning System (Space and Control Segments)	07	7,681	8,937		8,937	U
297	1203173F	Space and Missile Test and Evaluation Center	07	43,715	79,935		79,935	U
298	1203174F	Space Innovation, Integration and Rapid Technology Development	07	9,081	21,019		21,019	U
299	1203179F	Integrated Broadcast Service (IBS)	07	8,747	8,568		8,568	U
300	1203182F	Spacelift Range System (SPACE)	07	20,035	20,168		20,168	U
301	1203265F	GPS III Space Segment	07	233,043	141,892		141,892	U
302	1203400F	Space Superiority Intelligence	07	10,691	16,278		16,278	U
303	1203614F	JSpOC Mission System	07	125,191	70,383		70,383	U
304	1203620F	National Space Defense Center	07	18,052	55,309		55,309	U
305	1203699F	Shared Early Warning (SEW)	07	1,327				U
306	1203873F	Ballistic Missile Defense Radars	07					U

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289	1201017F	Global Sensor Integrated on Network (GSIN)	07	3,647				3,647	U
290	1201921F	Service Support to STRATCOM - Space Activities	07	988				988	U
291	1202140F	Service Support to SPACECOM Activities	07	11,863				11,863	U
292	1202247F	AF TENCAP	07						U
293	1203001F	Family of Advanced BLoS Terminals (FAB-T)	07	197,388				197,388	U
294	1203110F	Satellite Control Network (SPACE)	07	61,891				61,891	U
296	1203165F	NAVSTAR Global Positioning System (Space and Control Segments)	07						U
297	1203173F	Space and Missile Test and Evaluation Center	07	4,566				4,566	U
298	1203174F	Space Innovation, Integration and Rapid Technology Development	07	43,292				43,292	U
299	1203179F	Integrated Broadcast Service (IBS)	07						U
300	1203182F	Spacelift Range System (SPACE)	07	10,837				10,837	U
301	1203265F	GPS III Space Segment	07	42,440				42,440	U
302	1203400F	Space Superiority Intelligence	07	14,428				14,428	U
303	1203614F	JSpOC Mission System	07	72,762				72,762	U
304	1203620F	National Space Defense Center	07	2,653				2,653	U
305	1203699F	Shared Early Warning (SEW)	07						U
306	1203873F	Ballistic Missile Defense Radars	07	15,881				15,881	U

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307	1203906F	NCMC - TW/AA System	07	5,000				U
308	1203913F	NUDET Detection System (SPACE)	07	31,304	19,778		19,778	U
309	1203940F	Space Situation Awareness Operations	07	86,173	19,572		19,572	U
310	1206423F	Global Positioning System III - Operational Control Segment	07	492,986	509,258		509,258	U
311	1206770F	Enterprise Ground Services	07					U
9999	9999999999	Classified Programs		16,789,633	16,859,524	161,790	17,021,314	U
		Operational Systems Development		22,442,379	23,153,697	308,439	23,462,136	
Total Research, Development, Test & Eval, AF				38,077,597	41,166,683	321,934	41,488,617	

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307	1203906F	NCCM - TW/AA System	07						U
308	1203913F	NUDET Detection System (SPACE)	07	49,300				49,300	U
309	1203940F	Space Situation Awareness Operations	07	17,834				17,834	U
310	1206423F	Global Positioning System III - Operational Control Segment	07	445,302				445,302	U
311	1206770F	Enterprise Ground Services	07	138,870				138,870	U
9999	9999999999	Classified Programs		18,029,506	322,000	78,713	400,713	18,430,219	U
		Operational Systems Development		24,529,488		83,913	405,913	24,935,401	
Total Research, Development, Test & Eval, AF				45,616,122		128,248	450,248	46,066,370	

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21	03	0603216F	Aerospace Propulsion and Power Technology.....	Volume 1 - 279
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Personnel Administration	0901220F	285	07.....	Volume 3b - 647
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The following Program Elements are not providing RDT&E exhibits due to classification:

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0207424F EVALUATION AND ANALYSIS PROGRAM
0208161F SPECIAL EVALUATION SYSTEM
0208162F ADVANCED TECHNOLOGY PROGRAM
0301310F NATIONAL AIR INTELLIGENCE CENTER
0301314F COBRA BALL
0301315F MISSILE AND SPACE TECHICAL COLLECTION
0301324F FOREST GREEN
0301386F GDIP COLLECTION MANAGEMENT
0304111F SPECIAL ACTIVITES
0304311F SELECTED ACTIVITIES
0304348F ADVANCED GEOSPATIAL INTELLIGENCE (AGI)
0305124F SPECIAL APPLICATIONS PROGRAM
0305127F FOREIGN COUNTERINTELLIGENCE ACTIVITES
0305159F DEFENSE RECONNAISSANCE SUPPORT ACTIVITIES
0305172F COMBINED ADVANCED APPLICATIONS
0604446F WIDE AREA SURVEILLANCE - SP
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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** March 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force / BA 1: Basic Research</i>	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	320.961	383.322	356.107	0.000	356.107	363.097	370.504	384.410	391.617	Continuing	Continuing
613001: <i>Physics and Electronics</i>	-	94.693	113.504	105.346	0.000	105.346	107.406	109.604	113.708	115.841	Continuing	Continuing
613002: <i>Aerospace, Chemical and Material Sciences</i>	-	100.173	118.763	109.915	0.000	109.915	112.073	114.356	118.653	120.876	Continuing	Continuing
613003: <i>Mathematics, Information and Life Sciences</i>	-	95.920	114.438	105.513	0.000	105.513	107.590	109.780	113.901	116.036	Continuing	Continuing
613004: <i>Education and Outreach</i>	-	30.175	36.617	35.333	0.000	35.333	36.028	36.764	38.148	38.864	Continuing	Continuing

A. Mission Description and Budget Item Justification

Defense Research Sciences consists of extramural research activities in academia and industry along with in-house investigations performed in the Air Force Research Laboratory (AFRL). This program supports fundamental broad-based scientific and engineering research in areas critical to Air Force weapon, sensor, and support systems. All research areas are subject to long-range planning and technical review by both Air Force and tri-Service scientific planning groups. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 1, Basic Research because this budget activity includes scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** March 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force</i> / BA 1: <i>Basic Research</i>	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	342.919	348.322	354.360	0.000	354.360
Current President's Budget	320.961	383.322	356.107	0.000	356.107
Total Adjustments	-21.958	35.000	1.747	0.000	1.747
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	35.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-0.014	0.000			
• SBIR/STTR Transfer	-8.786	0.000			
• Other Adjustments	-13.158	0.000	1.747	0.000	1.747

Congressional Add Details (\$ in Millions, and Includes General Reductions)

	FY 2018	FY 2019
Project: 613001: <i>Physics and Electronics</i>		
Congressional Add: <i>Program Increase - Basic Research</i>	0.000	11.000
Congressional Add Subtotals for Project: 613001	0.000	11.000
Project: 613002: <i>Aerospace, Chemical and Material Sciences</i>		
Congressional Add: <i>Program Increase - Basic Research</i>	0.000	11.000
Congressional Add Subtotals for Project: 613002	0.000	11.000
Project: 613003: <i>Mathematics, Information and Life Sciences</i>		
Congressional Add: <i>Program Increase - Basic Research</i>	0.000	11.000
Congressional Add Subtotals for Project: 613003	0.000	11.000
Project: 613004: <i>Education and Outreach</i>		
Congressional Add: <i>Program Increase - Basic Research</i>	0.000	2.000
Congressional Add Subtotals for Project: 613004	0.000	2.000
Congressional Add Totals for all Projects	0.000	35.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force		Date: March 2019
Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force</i> / BA 1: <i>Basic Research</i>	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	
Change Summary Explanation Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358. Increase in FY 2020 due to civilian pay inflation adjustment.		

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: March 2019		
Appropriation/Budget Activity 3600 / 1					R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>				Project (Number/Name) 613001 / <i>Physics and Electronics</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
613001: <i>Physics and Electronics</i>	-	94.693	113.504	105.346	0.000	105.346	107.406	109.604	113.708	115.841	Continuing	Continuing

A. Mission Description and Budget Item Justification

Basic research in the Physics and Electronics Project seeks to enable revolutionary advances and expand the fundamental knowledge supporting technologies critical to the future of the Air Force. Research stresses high-risk, far-term, game-changing capability breakthroughs essential for future leaps in warfighter system performance, functionality, reliability, and survivability while simultaneously reducing component and system power, size, mass, and life cycle costs. Major areas being investigated in this project are complex electronics and fundamental quantum processes; plasma physics and high energy density non-equilibrium processes; and lasers and optics, electromagnetics, communication, and signal processing. While the following specific sub-areas are the focus of the project, there is interest in exploring novel ideas that may bridge these major efforts as well as those in the other projects within this program.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Complex Electronics and Fundamental Quantum Processes</p> <p>Description: Scientific focus areas are atomic and molecular physics, photonics, quantum electronic solids, gigahertz-terahertz electronics and material, semiconductor and electromagnetic materials, and optoelectronics.</p> <p>FY 2019 Plans: Continue to explore a wide range of complex materials and devices, including non-linear optical materials, photonics, optoelectronics, meta-materials, cathodes, dielectric and magnetic materials, memristive systems, new classes of high-temperature superconductors, quantum dots, quantum wells and graphene. Includes generating and controlling quantum states, such as superposition and entanglement, in photons and ultracold atoms and molecules.</p> <p>FY 2020 Plans: Continue to explore a wide range of complex materials and devices, including non-linear optical materials, photonics, optoelectronics, metamaterials, cathodes, dielectric and magnetic materials, memristive systems, new classes of high-temperature superconductors, quantum dots, quantum wells and graphene. Includes generating and controlling quantum states, such as superposition and entanglement, in photonic systems, quantum dots and defects in solids, and ultracold atoms and molecules.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.150 million. Funding increased due to added emphasis in complex electronics and fundamental quantum processes.</p>	38.328	41.489	42.639
<p>Title: Plasma Physics and High Energy Density Non-Equilibrium Processes</p> <p>Description: Scientific focus areas are plasma, electro-energetic physics and space sciences.</p> <p>FY 2019 Plans:</p>	19.742	21.371	21.964

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: March 2019	
Appropriation/Budget Activity 3600 / 1	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	Project (Number/Name) 613001 / <i>Physics and Electronics</i>	
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019
<p>Continue to explore a wide range of activities characterized by processes sufficiently energetic to require understanding and managing plasma phenomenology and the non-linear response of materials to high electric and magnetic fields. Includes space weather, plasma discharges, RF propagation, RF-plasma interaction, and high-power, beam-driven microwave devices.</p> <p>FY 2020 Plans: Continue to explore a wide range of activities characterized by processes sufficiently energetic to require understanding and managing plasma phenomenology and the non-linear response of materials to high electric and magnetic fields. Includes space weather, plasma discharges, RF propagation, RF-plasma interaction, and high-power, beam-driven microwave devices.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.593 million. Justification for the increase is described in the plans above.</p>			
<p>Title: Lasers and Optics, Electromagnetics, Communication and Signal Processing</p> <p>Description: Scientific focus areas are physical mathematics and applied analysis, novel computational methods, electromagnetics and wave propagation in complex media, ultra-fast dynamics, for revolutionary approaches to remote sensing and imaging physics, and surveillance and navigation.</p> <p>FY 2019 Plans: Continue to explore all aspects of producing and receiving electromagnetic and electro-optical signals, as well as their propagation through complex media, including adaptive optics and optical imaging. Continue to investigate aspects of the phenomenology of lasers including high energy lasers, non-linear optics, and ultra-short pulse laser science. Includes the development of sophisticated mathematics and algorithm development for extracting information from complex and/or sparse signals.</p> <p>FY 2020 Plans: Continue to explore all aspects of producing and receiving electromagnetic and electro-optical signals, as well as their propagation through complex media, including adaptive optics and optical imaging. Continue to investigate aspects of the phenomenology of lasers including high energy lasers, non-linear optics, and ultra-short pulse laser science. Includes the development of sophisticated mathematics and algorithm development for extracting information from complex and/or sparse signals.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.099 million. Funding increased due to added emphasis in lasers and optics, electromagnetics, communication and signal processing</p>		36.623	39.644
Accomplishments/Planned Programs Subtotals		94.693	102.504
		105.346	
		FY 2018	FY 2019
Congressional Add: Program Increase - Basic Research		0.000	11.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: March 2019
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Appropriation/Budget Activity 3600 / 1	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	Project (Number/Name) 613001 / <i>Physics and Electronics</i>
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	FY 2018	FY 2019
<i>FY 2018 Accomplishments:</i> N/A		
<i>FY 2019 Plans:</i> Conduct Congressionally directed effort.		
Congressional Adds Subtotals	0.000	11.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: March 2019		
Appropriation/Budget Activity 3600 / 1					R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>				Project (Number/Name) 613002 / <i>Aerospace, Chemical and Material Sciences</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
613002: <i>Aerospace, Chemical and Material Sciences</i>	-	100.173	118.763	109.915	0.000	109.915	112.073	114.356	118.653	120.876	Continuing	Continuing

A. Mission Description and Budget Item Justification

Basic research in the Aerospace, Chemical, and Materials Sciences Project seeks to enable revolutionary advances and expand the fundamental knowledge supporting technologies critical to the future of the Air Force. Research stresses high-risk, far-term, game-changing capability breakthroughs essential for future leaps in warfighter system performance, functionality, reliability, and survivability while simultaneously reducing component and system power, size, mass, and life cycle costs. Research topics include: aero-structure interactions and control; energy, power, and propulsion; complex materials and structures; and cross-disciplinary research reflecting the highly integrated nature of future weapon systems.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Aero Structure Interactions and Control</p> <p>Description: Scientific focus areas are high temperature aerospace materials, non-equilibrium aerothermodynamics and chemistry, unsteady, compressible flow turbulence, multiscale fluid-material interactions, and flow control.</p> <p>FY 2019 Plans: Continue to investigate the characterization, modeling, and exploitation of interactions between the unsteady aerodynamic flow field and the dynamic air vehicle structure to enable enhanced performance in next generation Air Force systems. Explore the synergy gained from an interdisciplinary look at multiple technologies and the integration of core disciplines of fluid mechanics, high-performance structures, and thermodynamics.</p> <p>FY 2020 Plans: Continue to investigate the characterization, modeling, and exploitation of interactions between the unsteady aerodynamic flow field and the dynamic air vehicle structure to enable enhanced performance in next generation Air Force systems. Explore the synergy gained from an interdisciplinary look at multiple technologies and the integration of core disciplines of fluid mechanics, high-performance structures, and thermodynamics.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.634 million. Justification for the increase is described in the plans above.</p>	29.527	31.763	32.397
<p>Title: Energy, Power, and Propulsion</p> <p>Description: Scientific focus areas are thermal control, theoretical chemistry, molecular dynamics, space power and propulsion, and combustion and diagnostics.</p>	31.855	34.269	34.953

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: March 2019
Appropriation/Budget Activity 3600 / 1	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	Project (Number/Name) 613002 / <i>Aerospace, Chemical and Material Sciences</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p><i>FY 2019 Plans:</i> Continue to exploit technological innovations and develop potentially revolutionary technologies by integrating core disciplines of combustion, plasma dynamics, chemistry, hybrid simulation, and structures. Investigate processes associated with the generation, storage, and utilization of energy, specifically for Air Force systems. This includes developing novel energetic materials as well as understanding and optimizing combustion processes.</p> <p><i>FY 2020 Plans:</i> Continue to exploit technological innovations and develop potentially revolutionary technologies by integrating core disciplines of combustion, plasma dynamics, chemistry, hydrodynamics, structural dynamics, and multi-fidelity simulations. Investigate processes associated with the generation, storage, and utilization of energy, specifically for Air Force systems. This includes developing novel energetic materials as well as understanding optimizing and controlling combustion processes.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.684 million. Justification for the increase is described in the plans above.</p>			
<p><i>Title:</i> Complex Materials and Structures</p> <p><i>Description:</i> Scientific focus areas are design, manufacturing, and dynamics and control of multifunctional materials and microsystems, multi-scale mechanics, diagnostics and prognosis, and physico-chemistry of novel organic materials.</p> <p><i>FY 2019 Plans:</i> Continue to investigate multifunctional materials and structures composed of different classes of materials, both organic and inorganic, that may be able to change functionality or performance characteristics to enhance the mission versatility of future air and space systems, with a key goal of increasing functionality while decreasing weight and volume. Explore materials, microsystems, and structures that incorporate hierarchical design and functionality from the nano-scale through the mesoscale, ultimately leading to controlled, well-understood material or structural behavior capable of dynamic functionality and/or performance characteristics to enhance mission versatility.</p> <p><i>FY 2020 Plans:</i> Continue to investigate multifunctional materials and structures composed of different classes of materials, both organic and inorganic, that can adapt to environmental constraints or mission requirements. Explore complex materials, microsystems, and structures that incorporate hierarchical design and functionality from the nano-scale through the mesoscale, ultimately leading to controlled, well-understood material or structural behavior capable of dynamic functionality and/or performance characteristics to enhance mission versatility.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i></p>	38.791	41.731	42.565

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: March 2019
Appropriation/Budget Activity 3600 / 1	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	Project (Number/Name) 613002 / <i>Aerospace, Chemical and Material Sciences</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$0.834 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	100.173	107.763	109.915

	FY 2018	FY 2019
Congressional Add: Program Increase - Basic Research	0.000	11.000
FY 2018 Accomplishments: N/A		
FY 2019 Plans: Conduct Congressionally directed effort.		
Congressional Adds Subtotals	0.000	11.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: March 2019		
Appropriation/Budget Activity 3600 / 1					R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>				Project (Number/Name) 613003 / <i>Mathematics, Information and Life Sciences</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
613003: <i>Mathematics, Information and Life Sciences</i>	-	95.920	114.438	105.513	0.000	105.513	107.590	109.780	113.901	116.036	Continuing	Continuing

A. Mission Description and Budget Item Justification

Basic research in the Mathematics, Information Sciences, and Life Sciences seeks to expand fundamental knowledge and enable revolutionary advances and supporting technologies critical to the future of the Air Force. Major areas being investigated in this project are data fusion, machine learning and artificial intelligence, information and complex networks, cyber-security, autonomous decision making, dynamical systems, optimization and control, and natural materials and systems. While the following are specific sub-areas within this project, there is a continuing interest to explore novel ideas to bridge disciplines within this program.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Information and Complex Networks	24.452	26.369	26.898
Description: Scientific focus areas are information operations and security, data and information fusion, advanced computing, artificial intelligence and complex networks.			
FY 2019 Plans: Continue to design and analyze techniques to enable reliable and secure exchange of information and predictable operation of networks and systems. This includes traditional aspects of information assurance, software engineering, and reliable systems, but the emphasis is on the underlying mathematics of secure-by-design architectures of networked communications and neural information processing. Sub-areas include system and network performance prediction, design and analysis, and modeling of human-machine systems.			
FY 2020 Plans: Continue to design and analyze techniques to enable reliable and secure exchange of information and predictable operation of networks and systems, including hardware and software interactions. This includes traditional aspects of information assurance, but with an emphasis on the underlying mathematics of secure-by-design architectures of networked communications and neural information processing. Analyze, optimize and design multi-scale networks with resilient features against noise and corruption from difficult environments and adversarial operations, using rigorous mathematical models of information exchange, physical operations, and human-machine interactions. Develop new computing approaches and algorithms for network-of-network information processing at the speed of warfare. Develop new mathematical approaches for predictive, multi-scale and multi-physics simulations of Air Force systems and systems-of-systems in realistic environments.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.529 million. Justification for the increase is described in the plans above.			
Title: Decision Making	19.070	20.565	20.978

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: March 2019
Appropriation/Budget Activity 3600 / 1	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	Project (Number/Name) 613003 / <i>Mathematics, Information and Life Sciences</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Description: Scientific focus areas are mathematical modeling of cognition and decision making, development and testing of advanced representations and processes for higher-level artificial intelligence, trust between humans and autonomous agents, mixed human-machine decision making, and computational social science for asymmetric threat detection and predictive large-scale influence.</p> <p>FY 2019 Plans: Continue to investigate new mathematical laws, scientific principles, and robust algorithms that underlie intelligent, mixed human-machine decision making to achieve accurate real-time projection of expertise and knowledge into and out of the battlespace. This includes efforts to advance the critical knowledge base in information sciences and information fusion, and to model individual and group cognitive processing and decision making.</p> <p>FY 2020 Plans: Continue to investigate new mathematical laws, scientific principles, and robust algorithms that underlie intelligent, mixed human-machine decision-making to achieve accurate real-time integration of human expertise and knowledge into a machine-based battlespace network. Develop new mathematical models for information capture; object, scene and relation identification; and multi-level reasoning and meta-learning. Advance the critical knowledge base in modeling of individual and group cognitive processing and decision making, and construct advanced methodologies for predictive, verifiable simulations of large-scale socio-cultural and human-machine hybrid networks.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.413 million. Justification for the increase is described in the plans above.</p>			
<p>Title: Dynamical Systems, Optimization, and Control</p> <p>Description: Scientific focus areas are computer models of dynamical data and communication networks, data-fusion, dynamics and control theory for multi-scale and complex networks, and mathematics of distributed optimization in uncertain, variable, continuous and discrete networked systems. Includes the development of advanced computing architectures for solving optimization and data-fusion problems in real time and by embedded processors in autonomous or semi-autonomous platforms.</p> <p>FY 2019 Plans: Continue to develop new scientific concepts supported by rigorous analysis for advancing the science of autonomy and promoting the understanding necessary to analyze and design complex multi-scale systems as well as provide guaranteed levels of performance. This includes developing novel adaptive control strategies for coordinating heterogeneous, autonomous, or semi-autonomous aerospace vehicles in uncertain, information rich, dynamically changing, adversarial, and networked environments.</p> <p>FY 2020 Plans:</p>	25.206	27.180	27.725

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: March 2019
Appropriation/Budget Activity 3600 / 1	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	Project (Number/Name) 613003 / <i>Mathematics, Information and Life Sciences</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Continue to develop new scientific concepts supported by rigorous analysis for advancing the science of autonomy and promoting the understanding necessary to analyze and design complex multi-scale systems as well as provide guaranteed levels of performance. Develop novel adaptive control strategies for coordinating heterogeneous, autonomous, or semi-autonomous aerospace vehicles in uncertain, information rich, dynamically changing, adversarial, and networked environments. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.545 million. Justification for the increase is described in the plans above.			
Title: Natural Materials and Systems Description: Scientific focus areas are natural materials and nature inspired systems, human performance and biosystems, cognitive neuroscience and biophysics. FY 2019 Plans: Continue to investigate multi-disciplinary approaches for studying the ways natural systems accomplish their required tasks. Study how to adapt and mimic existing natural sensory systems and add existing capabilities to these organisms with the intent to gain more precise control over their material production. FY 2020 Plans: Continue to investigate multi-disciplinary approaches for studying, using, mimicking, synthesizing and adapting to the ways natural systems are built, assembled and organized, and functioning to accomplish their objectives. Develop fundamental understanding of bio-chemical mechanisms and control procedures for the production and manufacture of natural materials, and develop reverse-engineering approaches to optimize the bio-chemical functionality. Develop approaches to adapt, blend and mimic existing natural sensory systems and neural systems of varying complexity, to add existing capabilities to these organisms and design in-silico replicas with similar or advanced capabilities. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.588 million. Justification for the increase is described in the plans above.	27.192	29.324	29.912
Accomplishments/Planned Programs Subtotals	95.920	103.438	105.513

	FY 2018	FY 2019
Congressional Add: Program Increase - Basic Research	0.000	11.000
FY 2018 Accomplishments: N/A		
FY 2019 Plans: Conduct Congressionally directed effort.		
Congressional Adds Subtotals	0.000	11.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: March 2019
Appropriation/Budget Activity 3600 / 1	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	Project (Number/Name) 613003 / <i>Mathematics, Information and Life Sciences</i>

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: March 2019		
Appropriation/Budget Activity 3600 / 1					R-1 Program Element (Number/Name) PE 0601102F / Defense Research Sciences				Project (Number/Name) 613004 / Education and Outreach			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
613004: <i>Education and Outreach</i>	-	30.175	36.617	35.333	0.000	35.333	36.028	36.764	38.148	38.864	Continuing	Continuing

A. Mission Description and Budget Item Justification

The major efforts in the Science and Technology (S&T) Education and Outreach Project are to facilitate interactions between the international and domestic research communities and Air Force researchers, and to support and develop scientists and engineers with an awareness of Air Force basic research priorities. These professional interactions and collaborations benefit the Air Force by increasing awareness of Air Force basic research priorities in the research community as a whole, and attracting talented scientists and engineers to address Air Force needs. International interactions facilitate future interoperability of coalition systems and foster relationships with future coalition partners. This project also seeks to enhance interactions with Historically Black Colleges and Universities, Hispanic serving institutions, and other minority institutions.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Outreach to International S&T Community	10.625	12.189	12.441
Description: Foster international S&T cooperation by supporting direct interchanges with a broad range of key international researchers and communities. Identify and leverage international scientific advances when appropriate.			
FY 2019 Plans: Leverage international expertise and support international technology liaison missions to identify and maintain awareness of foreign science and technology developments. Explore current foreign investments and influence world-class scientific research on specific topics of Air Force interest. Pursue access to technical information on foreign research capabilities within our interests. Support international visits by scientists and high-level DoD S&T delegations, and provide primary interface to coordinate international S&T participation among DoD organizations.			
FY 2020 Plans: Continue to leverage international expertise and support international technology liaison missions to identify and maintain awareness of foreign science and technology developments. Explore current foreign investments and influence world-class scientific research on specific topics of Air Force interest. Pursue access to technical information on foreign research capabilities within our interests. Support international visits by scientists and high-level DoD S&T delegations, and provide primary interface to coordinate international S&T participation among DoD organizations.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.252 million. Justification for the increase is described in the plans above.			
Title: Outreach to U.S. S&T Workforce	19.550	22.428	22.892
Description: Strengthen science, mathematics, and engineering research and infrastructure in the U.S., thereby strengthening current and future Air Force S&T capabilities.			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: March 2019
Appropriation/Budget Activity 3600 / 1	R-1 Program Element (Number/Name) PE 0601102F / <i>Defense Research Sciences</i>	Project (Number/Name) 613004 / <i>Education and Outreach</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p><i>FY 2019 Plans:</i> Increase awareness of Air Force research needs and opportunities throughout the civilian scientific community, while simultaneously identifying, recruiting, and increasing opportunities for new investigators to participate in critical Air Force research. Support science, mathematics, and engineering research, and educational outreach programs including Historically Black Colleges and Universities, Hispanic serving institutions, and other minority institutions.</p> <p><i>FY 2020 Plans:</i> Continue identifying, recruiting, and increasing opportunities for new young investigators to participate in critical Air Force research. Support science, mathematics, and engineering research including Historically Black Colleges and Universities, Hispanic serving institutions, and other minority institutions. Support science activities that encourage elementary/middle/high school youths to develop an interest in and pursue higher education and employment in the science, mathematics, and engineering (STEM) fields.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.464 million. Justification for the increase is described in the plans above.</p>			
Accomplishments/Planned Programs Subtotals	30.175	34.617	35.333

	FY 2018	FY 2019
<i>Congressional Add:</i> Program Increase - Basic Research	0.000	2.000
<i>FY 2018 Accomplishments:</i> N/A		
<i>FY 2019 Plans:</i> Conduct Congressionally directed effort.		
Congressional Adds Subtotals	0.000	2.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 1: Basic Research</i>					R-1 Program Element (Number/Name) PE 0601103F / <i>University Research Initiatives</i>							
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	157.079	164.991	158.859	0.000	158.859	161.914	165.083	168.302	171.668	Continuing	Continuing
615094: <i>University Research Initiatives</i>	-	157.079	164.991	158.859	0.000	158.859	161.914	165.083	168.302	171.668	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program supports defense-related basic research in a wide range of scientific and engineering disciplines relevant to maintaining U.S. military technology superiority. Research topics include, but are not limited to, transformational and high priority technologies such as nanotechnology, sensor networks, artificial intelligence and information fusion, smart materials and structures, quantum materials and processes for sensing, communication and computing, efficient energy and power conversion, and high-energy materials for propulsion and control. The program also enhances and promotes the education of U.S. scientists and engineers in disciplines critical to maintaining, advancing, and enabling future U.S. defense technologies. For example, the National Defense Science and Engineering Graduate (NDSEG) program awards fellowships to train U.S. citizens in science and engineering disciplines of military importance under a joint tri-Service and Office of the Assistant Secretary of Defense for Research and Engineering competitive scholarship program. Finally, this program assists universities in establishing superior instrumentation capabilities needed to improve the quality of defense-related research and education. A fundamental component of this program is the recognition that future technologies and technology exploitations require highly coordinated and concerted multi- and inter-disciplinary efforts. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 1, Basic Research because this budget activity includes scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force</i> / BA 1: <i>Basic Research</i>	R-1 Program Element (Number/Name) PE 0601103F / <i>University Research Initiatives</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	147.923	154.991	158.859	0.000	158.859
Current President's Budget	157.079	164.991	158.859	0.000	158.859
Total Adjustments	9.156	10.000	0.000	0.000	0.000
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	15.000	10.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-5.844	0.000			
• Other Adjustments	0.000	0.000	0.000	0.000	0.000

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 615094: *University Research Initiatives*

Congressional Add: *Program Increase - Antenna Research*

Congressional Add: *Program Increase*

Congressional Add: *Program Increase - Basic Research*

Congressional Add Subtotals for Project: 615094

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	4.821	0.000
	9.641	0.000
	0.000	10.000
Congressional Add Subtotals for Project: 615094	14.462	10.000
Congressional Add Totals for all Projects	14.462	10.000

C. Accomplishments/Planned Programs (\$ in Millions)

Title: Multidisciplinary University Research Initiative

Description: Promote fundamental, multi- and interdisciplinary science and engineering research projects involving multiple principle investigators.

FY 2019 Plans:

Continue to fund competitive research grants at U.S. universities that focus on significantly expanding the basic knowledge of Air Force relevant science and technology areas, not normally achievable in smaller funded, single investigator awards. Support and recognize superior academic researchers in the early stages of their careers through the Presidential Early Career Award for Scientists and Engineers (PECASE) program. Continue funding of multi-disciplinary programs initially awarded in prior years.

FY 2020 Plans:

	FY 2018	FY 2019	FY 2020
	80.831	84.445	86.552

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 1: Basic Research</i>		R-1 Program Element (Number/Name) PE 0601103F / <i>University Research Initiatives</i>		
C. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Continue funding competitive research grants at U.S. universities that focus on significantly expanding the basic knowledge of Air Force-relevant science and technology areas, not normally achievable in smaller funded, single investigator awards. Support and recognize superior academic researchers in the early stages of their careers through the PECASE program. Continue funding of multi-disciplinary programs initially awarded in prior years.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$2.107 million. Funding increased due to added emphasis in multidisciplinary university research.</p>				
<p>Title: Science and Engineering Education</p> <p>Description: Support post-graduate, graduate, and undergraduate education in science and engineering disciplines at U.S. universities.</p> <p>FY 2019 Plans: Continue to award highly competitive National Defense Science and Engineering Graduate (NDSEG) fellowships. Support competitive awards for graduate and undergraduate research experiences, including those established under the Awards to Stimulate and Support Undergraduate Research Experiences (ASSURE) program. Continue funding for awards initiated under prior year DoD programs.</p> <p>FY 2020 Plans: Continue to award highly competitive NDSEG fellowships. Continue to support competitive awards for graduate and undergraduate research experiences, including those established under the ASSURE program. Continue funding for awards initiated under prior year DoD programs.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.389 million. Funding increased due to added emphasis in science and engineering education.</p>		47.528	55.652	57.041
<p>Title: Research Instrumentation</p> <p>Description: Enhance scientific and engineering research through advanced education infrastructure and instrumentation at U.S. universities.</p> <p>FY 2019 Plans:</p>		14.258	14.894	15.266

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force</i> / BA 1: <i>Basic Research</i>	R-1 Program Element (Number/Name) PE 0601103F / <i>University Research Initiatives</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Continue to award grants on a competitive basis under the Defense University Research Instrumentation Program (DURIP) to U.S. universities to acquire state-of-the-art, high technology instrumentation and infrastructure to enhance research and educational capabilities. FY 2020 Plans: Continue to award grants on a competitive basis under the DURIP to U.S. universities to acquire state-of-the-art, high technology instrumentation and infrastructure to enhance research and educational capabilities. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.372 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	142.617	154.991	158.859

	FY 2018	FY 2019
Congressional Add: Program Increase - Antenna Research FY 2018 Accomplishments: Conducted Congressionally directed effort. FY 2019 Plans: N/A	4.821	0.000
Congressional Add: Program Increase FY 2018 Accomplishments: Conducted Congressionally directed effort. FY 2019 Plans: N/A	9.641	0.000
Congressional Add: Program Increase - Basic Research FY 2018 Accomplishments: N/A FY 2019 Plans: Conduct Congressionally directed effort.	0.000	10.000
Congressional Adds Subtotals	14.462	10.000

D. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity
3600: *Research, Development, Test & Evaluation, Air Force I BA 1: Basic Research*

R-1 Program Element (Number/Name)
PE 0601103F / *University Research Initiatives*

F. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 1: Basic Research</i>					R-1 Program Element (Number/Name) PE 0601108F / <i>High Energy Laser Research Initiatives</i>							
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	13.462	13.016	14.795	0.000	14.795	15.090	15.397	15.708	16.022	Continuing	Continuing
615097: <i>High Energy Laser Research Initiatives</i>	-	13.462	13.016	14.795	0.000	14.795	15.090	15.397	15.708	16.022	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program funds basic research aimed at developing fundamental scientific knowledge to support future Department of Defense Directed Energy Weapon systems through the Joint Directed Energy Transition Office. This program funds multi-disciplinary research institutes to conduct research on laser and beam control technologies. In addition, this program supports educational grants to stimulate student interest in directed energy and encourage graduate research in topics related to high energy lasers and high power microwaves. These educational grants are used for educational tools, scholarships, and summer intern employees in military laboratories. Efforts in this program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 1, Basic Research because this budget activity includes scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 1: Basic Research	R-1 Program Element (Number/Name) PE 0601108F I High Energy Laser Research Initiatives
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	14.417	14.506	14.795	0.000	14.795
Current President's Budget	13.462	13.016	14.795	0.000	14.795
Total Adjustments	-0.955	-1.490	0.000	0.000	0.000
• Congressional General Reductions	0.000	-0.040			
• Congressional Directed Reductions	0.000	-1.450			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-0.522	0.000			
• Other Adjustments	-0.433	0.000	0.000	0.000	0.000

Change Summary Explanation

Decrease in FY 2019 due to a Congressional directed reduction in the Department of Defense Appropriation Act 2019 for under-execution.

C. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Directed Energy Sources and Devices	6.272	6.020	6.766	0.000	6.766
Description: Improve the fundamental understanding and modeling of high energy laser and high power microwave sources and devices.					
In FY 2019, this effort was named High Energy Laser Sources and Devices. The effort name was changed to reflect the direction in the 2017 and 2018 National Defense Authorization Acts.					
FY 2019 Plans: Investigate innovative laser technologies in diode-pumped alkali lasers, short-pulse, fiber, and solid state laser technologies. Leverage international technology advancements.					
FY 2020 Base Plans: Continue investigations into innovative laser technologies in diode-pumped alkali lasers, short-pulse, fiber, and solid state laser technologies. Continue overseas efforts to leverage international technology advancements. Initiate investigations into innovative high power microwave technologies.					
FY 2020 OCO Plans:					

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 1: Basic Research	R-1 Program Element (Number/Name) PE 0601108F I High Energy Laser Research Initiatives
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Not Applicable					
<p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.746 million. Justification for the increase is described in the plans above.</p>					
<p>Title: Directed Energy Propagation technologies</p> <p>Description: Improve the fundamental understanding and modeling of beam control technologies as they relate to High Energy Laser applications and High Power Microwaves. Conduct research in atmospheric characterization, metrology, control systems, algorithms, waveguides, antennas and beam control component technology.</p> <p>In FY 2019, this effort was named High Energy Laser Beam Control. The effort name was changed to reflect the direction in the 2017 and 2018 National Defense Authorization Acts.</p> <p>FY 2019 Plans: Research innovative high energy laser beam control architectures. Leverage international research developments and technology advancements.</p> <p>FY 2020 Base Plans: Continue to research innovative high energy laser beam control architectures. Continue to leverage international research developments and technology advancements.</p> <p>FY 2020 OCO Plans: Not Applicable.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.906 million. Justification for the increase is in the plans above.</p>	6.069	5.873	6.779	0.000	6.779
<p>Title: Directed Energy Education</p> <p>Description: Fund educational grants to stimulate student interest in directed energy.</p> <p>In FY 2019, this effort was named High Energy Laser Education. The effort name was changed to reflect the direction in the 2017 and 2018 National Defense Authorization Acts.</p> <p>FY 2019 Plans:</p>	1.121	1.123	1.250	0.000	1.250

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 1: Basic Research</i>	R-1 Program Element (Number/Name) PE 0601108F / <i>High Energy Laser Research Initiatives</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Provide scholarships and internships to support college students studying in fields related to high energy lasers and high power microwaves. Provide grants to Service Academies to stimulate studies related to directed energy among military cadets. Fund publication of journals and support continuing education for professionals in the directed energy field.</p> <p>FY 2020 Base Plans: Continue to provide scholarships and internships to support college students studying in fields related to high energy lasers and high power microwaves. Continue to provide grants to Service Academies to stimulate studies related to directed energy among military cadets. Continue to fund publication of journals and support continuing education for professionals in the directed energy field.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.127 million. Justification for the increase is described in the plans above.</p>					
Accomplishments/Planned Programs Subtotals	13.462	13.016	14.795	0.000	14.795

D. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	143.900	181.373	128.851	0.000	128.851	126.436	130.469	135.447	138.498	Continuing	Continuing
624347: <i>Materials for Structures, Propulsion, and Subsystems</i>	-	62.934	88.375	49.844	0.000	49.844	45.959	47.385	49.193	50.337	Continuing	Continuing
624348: <i>Materials for Electronics, Optics, and Survivability</i>	-	30.523	37.475	33.507	0.000	33.507	34.248	35.546	36.939	37.782	Continuing	Continuing
624349: <i>Materials Technology for Sustainment</i>	-	50.443	55.523	45.500	0.000	45.500	46.229	47.538	49.315	50.379	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops advanced materials, processing, and inspection technologies to reduce life cycle costs and improve performance, sustainability, availability, affordability, supportability, reliability, and survivability of current and future Air Force systems and operations. The program has three projects that develop: structural, propulsion, and sub-systems materials and processes technologies; electronic, optical, and survivability materials and processes technologies; and sustainment materials, processes technologies, and advanced non-destructive inspection methodologies. Efforts in the program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	124.264	125.373	136.526	0.000	136.526
Current President's Budget	143.900	181.373	128.851	0.000	128.851
Total Adjustments	19.636	56.000	-7.675	0.000	-7.675
• Congressional General Reductions	-0.025	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	25.000	56.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-2.567	0.000			
• Other Adjustments	-2.772	0.000	-7.675	0.000	-7.675

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 624347: *Materials for Structures, Propulsion, and Subsystems*

Congressional Add: *Program increase - Structures, propulsion, and subsystems*

Congressional Add: *Program increase - Certification of advanced composites*

Congressional Add: *Program Increase - Thermal Protection for Hypersonic Vehicles*

Congressional Add: *Program Increase - High Temperature Material Technologies for Turbine Engines*

Congressional Add: *Program Increase - High Performance Materials*

Congressional Add: *Program Increase - Turbine Airfoil Demonstration*

Congressional Add Subtotals for Project: 624347

	FY 2018	FY 2019
	4.914	0.000
	14.742	15.000
	0.000	10.000
	0.000	5.000
	0.000	8.000
	0.000	3.000
	19.656	41.000
	0.000	5.000
	0.000	5.000
	4.914	0.000
	0.000	10.000
	4.914	10.000

Project: 624348: *Materials for Electronics, Optics, and Survivability*

Congressional Add: *Program Increase - Biosensor Materials*

Congressional Add Subtotals for Project: 624348

Project: 624349: *Materials Technology for Sustainment*

Congressional Add: *Program Increase - Coatings*

Congressional Add: *Program Increase - Coating Technologies*

Congressional Add Subtotals for Project: 624349

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>
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Congressional Add Details (\$ in Millions, and Includes General Reductions)		FY 2018		FY 2019
	Congressional Add Totals for all Projects	24.570		56.000

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

Decrease in FY 2020 due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>				Project (Number/Name) 624347 / <i>Materials for Structures, Propulsion, and Subsystems</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624347: <i>Materials for Structures, Propulsion, and Subsystems</i>	-	62.934	88.375	49.844	0.000	49.844	45.959	47.385	49.193	50.337	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops the materials and processing technology base for aircraft, spacecraft, launch systems, and missiles to improve affordability, maintainability, and performance of current and future Air Force systems. A family of affordable lightweight materials is being developed, including metals, polymers, ceramics, metallic and nonmetallic composites, and hybrid materials to provide upgraded capabilities for existing aircraft, missile, and propulsion systems to meet the future system requirements. The project develops high-temperature turbine engine materials that will enable engine designs to improve turbine engine thrust-to-weight ratio, specific fuel consumption and affordability. Advanced high temperature protection materials are being developed that are affordable, lightweight, dimensionally stable, thermally conductive, and/or ablation and erosion resistant to meet aerospace and missile requirements. Alternative or replacement materials are being developed to maintain the performance of aging operational systems. The project concurrently develops advanced processing methods to enable adaptive processing of aerospace materials.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Ceramics and Composites	25.585	27.951	29.552	0.000	29.552
Description: Develop ceramic, ceramic matrix composite, and hybrid materials technologies for performance and supportability improvement in propulsion systems and high temperature aerospace structures.					
FY 2019 Plans: Demonstrate and mature new advanced processing methods, coating technologies, and behavioral life prediction for higher temperature capable organic and ceramic matrix composites. Continue to analyze severe environment durability of advanced composite systems via mechanical testing. Continue development of new ceramic and polymer matrix composite materials and processes with higher temperature capability for next generation propulsion systems and aerospace structures. Continue to advance and integrate the computational material science infrastructure for composite materials in an effort to accelerate the development and certification of advanced composite materials. Continue to verify and validate damage progression models on increasingly complex polymer matrix composite structural applications. Continue development of composite damage progression models for application in an engineering environment.					
FY 2020 Base Plans: Demonstrate and mature new advanced processing methods, coating technologies, and behavioral life prediction concepts for current and future higher capability polymer and ceramic matrix composites. Continue in-depth analyses and assessment of severe environment durability of advanced composite systems via					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624347 / <i>Materials for Structures, Propulsion, and Subsystems</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>mechanical testing. Continue developing and testing the new ceramic and polymer matrix composite materials and processes with higher temperature capability for next generation propulsion systems and aerospace structures. Continue to advance and integrate the computational material science infrastructure for composite materials to model, characterize, and accelerate the development and certification of advanced composite materials. Continue to verify and validate damage progression models on increasingly complex polymer matrix composite structural applications. Continue newer testing and assessment methods to development composite damage progression models for application in an engineering environment. Develop and refine modeling tools to link processing to performance of organic/polymer matrix composites and expand damage mechanics models to increasingly complex composite materials. Develop and validate the development and exploration of materials to meet evolving requirements for structural hardening.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.601 million. Funding increased due to added emphasis and demand for high temperature ceramics and composite technologies for hypersonic vehicles.</p>					
<p>Title: Metals</p> <p>Description: Develop lightweight and high temperature metallics, life prediction, and metals processing technologies for increased affordability, durability, and reliability.</p> <p>FY 2019 Plans: Continue demonstration and implementation of advanced computation methods to support material development and characterization modeling. Continue to validate quantitative, predictive models for performance of metallic based thermal management systems through coupon testing. Continue to analyze relationships between microstructure, processing, properties, and performance of metallic, hybrid, nanoscale, and gradient metallic materials. Validate and continue development of affordable integrated material/manufacturing and component analysis for life management and development of affordable structural materials innovative research. Continue to advance development of next generation turbine engine disk and reliable affordable metallic structural components through computational methods. Validate the value of integrated analytical tools in the optimization of design and certification of additively manufactured metallic components. Continue development and refine low cost processing methods for low cost, attritable propulsion systems.</p> <p>FY 2020 Base Plans:</p>	13.268	14.686	15.283	0.000	15.283

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624347 / <i>Materials for Structures, Propulsion, and Subsystems</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Continue demonstration and implementation of advanced computation methods to support material development and characterization modeling. Continue to analyze relationships between microstructure, processing, properties, and performance of affordable metallic and high performance gradient metallic materials. Validate integrated material/manufacturing and component analysis for life management and development of affordable structural metals and low cost processes. Continue to advance reliable affordable metallic structural components through computational methods. Validate the value of integrated analytical tools in the optimization of design and certification of additively manufactured metallic components. Continue development and refine low cost processing methods and affordable metals for low cost, attritable propulsion systems. Initiate development of enhanced life management practices to incorporate effects of engineered residual stress. Continue research on application of advanced data science, artificial intelligence and machine learning on materials science problems.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.597 million. Funding increased due to added emphasis in computational models to speed up research on metal testing and behavior predictability.</p>					
<p>Title: Thermal Protection Materials</p> <p>Description: Develop and evaluate lightweight, active, adaptive, multifunctional, high temperature, and durable material systems for extreme environments and hypersonic applications.</p> <p>FY 2019 Plans: Mature processing methods for fabricating materials required for expendable hypersonic applications. Continue to validate, and develop and refine unique experimental techniques to assess mechanical properties and time-dependent behavior. Continue to validate and demonstrate material properties and performance to meet design needs for control surfaces, leading edges, and apertures. Continue to develop computational models to assess environmental degradation of materials in a hypersonic environment.</p> <p>FY 2020 Base Plans: Mature processing methods for fabricating materials required for expendable hypersonic applications. Validate, develop and refine unique experimental techniques to assess mechanical properties and time-dependent behavior. Continue to validate and demonstrate material properties and performance to meet design needs for control surfaces, leading edges, aero shells, and apertures. Further the development of computational models to</p>	4.425	4.738	5.009	0.000	5.009

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624347 / <i>Materials for Structures, Propulsion, and Subsystems</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
assess environmental degradation of materials in a hypersonic environment. Initiate development of materials to meet emerging requirements of systems for effective nuclear deterrence. FY 2020 OCO Plans: Not Applicable FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.271 million. Justification for the increase is described in the plans above.					
Accomplishments/Planned Programs Subtotals	43.278	47.375	49.844	0.000	49.844

	FY 2018	FY 2019
Congressional Add: Program increase - Structures, propulsion, and subsystems FY 2018 Accomplishments: Conducted Congressionally directed efforts. FY 2019 Plans: Not Applicable	4.914	0.000
Congressional Add: Program increase - Certification of advanced composites FY 2018 Accomplishments: Conducted Congressionally directed efforts. FY 2019 Plans: Conduct Congressionally directed efforts.	14.742	15.000
Congressional Add: Program Increase - Thermal Protection for Hypersonic Vehicles FY 2018 Accomplishments: Not Applicable FY 2019 Plans: Conduct Congressionally directed efforts.	0.000	10.000
Congressional Add: Program Increase - High Temperature Material Technologies for Turbine Engines FY 2018 Accomplishments: Not Applicable FY 2019 Plans: Conduct Congressionally directed efforts.	0.000	5.000
Congressional Add: Program Increase - High Performance Materials FY 2018 Accomplishments: Not Applicable FY 2019 Plans: Conduct Congressionally directed efforts.	0.000	8.000
Congressional Add: Program Increase - Turbine Airfoil Demonstration	0.000	3.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624347 / <i>Materials for Structures, Propulsion, and Subsystems</i>
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	FY 2018	FY 2019
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts.		
Congressional Adds Subtotals	19.656	41.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A.

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>				Project (Number/Name) 624348 / <i>Materials for Electronics, Optics, and Survivability</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624348: <i>Materials for Electronics, Optics, and Survivability</i>	-	30.523	37.475	33.507	0.000	33.507	34.248	35.546	36.939	37.782	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops materials technologies for Intelligence, Surveillance, and Reconnaissance (ISR), situational awareness, and low-observable systems and subsystems for aircraft and missile applications, including sensor, microwave, and short, mid, and long-wave infrared (SWIR, MWIR, LWIR) detection and countermeasures devices used for targeting, electronic warfare, and active aircraft protection. Materials for protection of aircrews, sensors, and aircraft from laser, and high-power microwave directed energy threats are also developed. Electronic and optical materials are being developed to enable surveillance and situational awareness with faster operating speeds, greater tunability, higher power output, improved thermal management (including higher operating temperatures), greater sensitivity, and extended dynamic range. New materials are being developed to counter the most prominent laser threats and to respond to emerging and agile threat wavelengths without impairing mission effectiveness. The project develops nanostructured and biological materials for aircraft structures, munitions, air vehicle subsystems, and personnel. The project develops novel materials for electromagnetic interactions with matter for electromagnetic pulse, high power microwave, and lightning strike protection.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Infrared Detector and Electromagnetic Device Materials	10.403	10.716	11.090	0.000	11.090
Description: Develop infrared (IR) detector and Electro-magnetic device materials and processes technologies for performance, affordability, and operational capability of surveillance, tracking, targeting, and situational awareness systems.					
FY 2019 Plans: Continue to develop and demonstrate materials and processes for control and detection of electromagnetic radiation for Intelligence, Surveillance, Reconnaissance (ISR) technologies. Continue to develop and demonstrate materials for use in high resolution imaging by electromagnetic radiation. Continue to demonstrate nanoscale materials, meta materials, and models for use in producing detectors. Continue to utilize computational materials science to improve performance prediction and reliability models. Continue to analyze quantum materials for aerospace applications. Continue to develop and demonstrate SWIR detector materials and hyper-spectral LWIR materials. Continue to validate materials and processes for integration of radio frequency and optical signals as well as concepts for novel optical devices and components. Validate and					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624348 / <i>Materials for Electronics, Optics, and Survivability</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>continue development of photonics for air vehicle applications. Continue to demonstrate nanostructured materials for components to enable agile radio frequency capability.</p> <p>FY 2020 Base Plans: Continue advanced development, demonstration and validation of materials and processes for control and detection of electromagnetic radiation for Intelligence, Surveillance, Reconnaissance (ISR) technologies. Further the development, testing, and assessment of materials for use in high resolution imaging by electromagnetic radiation and demonstrate the results. Proceed with advanced demonstration of nanoscale materials, meta materials, and models for use in producing detectors. Continue to utilize all aspects of computational materials science to improve performance prediction and reliability models, as well as analyzing quantum materials for aerospace applications. Continue specific development and demonstration of short wave infrared detector materials and hyper-spectral long wave infrared materials. Verify and validate materials and processes for integration of radio frequency and optical signals as well as concepts for novel optical devices and components. Validate generated data and continue development of photonics for air vehicle applications, and demonstrate nanostructured materials for components to enable agile radio frequency capability.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.374 million. Funding increased due to added emphasis in electromagnetic radiation, nanoscale materials, and meta materials.</p>					
<p>Title: Directed Energy Hardened Materials</p> <p>Description: Develop and demonstrate technologies to enhance the safety, survivability, and mission effectiveness of aircrews, sensors, viewing systems, and related assets.</p> <p>FY 2019 Plans: Analyze and validate a plethora of materials and technologies to protect against directed energy threats. Develop, validate, and demonstrate advanced optical limiter materials for damage protection, enhanced hybrid materials for advanced applications in airborne, space, and personnel systems. Continue to assess response of new materials for high-energy laser interactions. Continue to develop approaches for integration of multi-modal</p>	10.979	12.341	12.672	0.000	12.672

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624348 / <i>Materials for Electronics, Optics, and Survivability</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>hardening into structures and devices. Continue to validate repeatability and continue to utilize computational materials science to enhance multi-scale modeling for design of robust, reliable integrated protection.</p> <p>FY 2020 Base Plans: Continue to analyze and validate the comprehensive generated data of materials and technologies to protect against directed energy threats. Develop and demonstrate advanced optical limiter materials for damage protection, enhanced hybrid materials for advanced applications, and continue to assess response of new materials for high-energy laser interactions. Continue developing the novel approaches for integration of multi-modal hardening into structures and devices. Continue to assess data and validate repeatability and utilize computational materials science to enhance multi-scale modeling for design of robust, reliable integrated protection. Initiate development of proven selected advanced materials technologies to protect against nuclear flash blindness.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.331 million. Justification for the increase is described in the plans above.</p>					
<p>Title: Laser Source Materials</p> <p>Description: Develop materials to enable higher performance high power laser sources (quasi-Continuous Wave to Continuous Wave) with emphasis on laser output in the mid-InfraRed spectral region (2-5 microns).</p> <p>FY 2019 Plans: Validate materials and process technologies to control and generate directed electromagnetic energy for survivability and other applications. Continue to demonstrate and model materials processes for controlling laser beam direction and focus with optical components. Continue to develop materials for frequency conversion, high power optical isolators, Mid-wave infrared (MWIR) Laser Sources and high power microwave sources for directed energy sources.</p> <p>FY 2020 Base Plans: Continue to validate materials and process technologies to control and generate directed electromagnetic energy for survivability and other applications. Further demonstrate and model materials processes for controlling laser</p>	1.261	1.299	1.344	0.000	1.344

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624348 / <i>Materials for Electronics, Optics, and Survivability</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>beam direction and focus with optical components, and materials for frequency conversion, high power optical isolators, mid-wave infrared laser sources and high power microwave sources for directed energy sources.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.045 million. Justification for the increase is described in the plans above.</p>					
<p>Title: Nanostructured and Biological Materials</p> <p>Description: Develop enabling and foundational biotechnologies for guidance and control, rapid tagging, tracking, and identification of targets, and bio-integrated electronics and sensing for Air Force applications.</p> <p>FY 2019 Plans: Continue to validate engineering, scientific and processing methods for nano and biological materials to address unique requirements for Air Force man-machine integration, and electronic components. Continue to explore biotechnology to assess the impact of microbes and fungi on Air Force systems. Continue to study reliable materials and processes to optimize components for compact, flexible, stretchable multi-functional devices. Continue to validate materials and process for functional additive manufacturing of electronic components. Continue to demonstrate methods to assess reliability of nano and bio materials and processes. Continue to support Flexible Hybrid Electronics Institute for Manufacturing Innovation and the NanoBio Manufacturing Consortium.</p> <p>FY 2020 Base Plans: Continue to validate and verify engineering, scientific and processing methods for nano and biological materials to address unique requirements for Air Force man-machine integration, and electronic components. Explore sustainability demand biotechnology to assess the impact of microbes and fungi on Air Force systems. Continue to study more robust and reliable materials and processes to optimize components for compact, flexible, stretchable multi-functional devices, and validate materials and process for functional additive manufacturing of electronic components. Demonstrate methods to assess reliability and field resiliency of nano and bio materials and processes. Continue to support Flexible Hybrid Electronics Institute for Manufacturing Innovation and the NanoBio Manufacturing Consortium for collaborative teaming.</p> <p>FY 2020 OCO Plans:</p>	7.880	8.119	8.401	0.000	8.401

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624348 / <i>Materials for Electronics, Optics, and Survivability</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Not Applicable					
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.282 million. Funding increased due to added emphasis in nano and biological materials development.					
Accomplishments/Planned Programs Subtotals	30.523	32.475	33.507	0.000	33.507

	FY 2018	FY 2019
<i>Congressional Add:</i> Program Increase - Biosensor Materials	0.000	5.000
<i>FY 2018 Accomplishments:</i> Not Applicable		
<i>FY 2019 Plans:</i> Conduct Congressionally directed efforts.		
Congressional Adds Subtotals	0.000	5.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A.

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>				Project (Number/Name) 624349 / <i>Materials Technology for Sustainment</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624349: <i>Materials Technology for Sustainment</i>	-	50.443	55.523	45.500	0.000	45.500	46.229	47.538	49.315	50.379	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops materials and processing technologies to support operational Air Force mission areas by providing the ability to inspect the quality of delivered systems, transitioning more reliable and maintainable materials, establishing a capability to detect and characterize performance threatening defects, characterizing materials processes and properties necessary for materials transition, and providing quick reaction support and failure analysis to the operational commands and repair centers. Repair techniques and nondestructive inspection/evaluation (NDI/E) methods are developed that are needed for metallic and non-metallic structures, coatings, corrosion control processes, and to support integration of composite structures for aerospace systems. Various NDI/E methods are essential to ensure optimum quality in the design and production of aircraft, propulsion, and missile systems. These NDI/E methods are also essential to monitor and detect the onset of any service-initiated damage and/or deterioration due to aging of operational systems.

B. Accomplishments/Planned Programs (\$ in Millions)

Title: Material State Awareness

Description: Develop Materials State Awareness technologies to identify and characterize materials and/or damage regardless of scale for managing the health of aging structures, propulsion systems, and low-observable materials/structures, plus enabling advanced materials qualification.

In 2019, the effort was named "Sensing Technologies"

FY 2019 Plans:

Continue to validate and demonstrate non-destructive evaluation modeling capabilities and use these competencies to drive improvements in capability to detect and characterize damage in realistic aerospace structures and engine components. Continue approaches to address the variability inherent in aerospace systems and materials and begin to quantify the impact of that variability on non-destructive inspection capability and reliability. Validate advanced sensing technologies to detect and characterize changes in material properties, damage evolution, and other factors that detrimentally affect aerospace systems. Continue development and validation of damage state awareness approaches and methodologies for use on aerospace structures and engine components. Validate and continue development of advanced methods, to monitor and evaluate material state awareness.

FY 2020 Base Plans:

FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
13.689	15.933	16.022	0.000	16.022

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624349 / <i>Materials Technology for Sustainment</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Continue to validate and demonstrate non-destructive evaluation modeling capabilities and use these competencies to drive improvements in capability to detect, characterize and quantify damage in realistic aerospace structures and engine components. Continue to analyze approaches to address the variability inherent in aerospace systems and materials and begin to quantify the impact of that variability on non-destructive inspection capability and reliability. Validate advanced sensing technologies to detect and characterize changes in material properties, damage evolution, and other factors that detrimentally affect aerospace systems. Continue development and validation of damage state awareness approaches and methodologies for use on aerospace structures and engine components. Validate and continue development of advanced methods to monitor and evaluate material state awareness. Continue development of augmented reality technologies to improve the process of performing non-destructive evaluation tasks, acquiring and archiving data and reporting results</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.089 million. Funding increased due to added emphasis in non-destructive technologies for sustainment.</p>					
<p>Title: Production and Repair Technologies</p> <p>Description: Develop support capabilities, information, and processes to resolve problems with materials in the production and repair of systems components and structures.</p> <p>FY 2019 Plans: Continue to substantiate repeatability and demonstrate advanced materials and processes technology to repair and extend the life of Air Force systems. Continue to refine through demonstration the understanding of material durability and repair limits for emerging Air Force systems. Continue to advance the analysis and development of improved lifecycle prediction test methods and techniques to understand effects of service environments, corrosion, residual stresses, and material processes on structural and functional materials. Improve the service life of advanced materials, processes and designs for improved repair and maintainability and life cycle cost of outer-moldline coatings, access panel treatments, and multifunctional systems. Continue to further advance specialty material affordability technologies and processes to reduce maintenance costs of these materials.</p> <p>FY 2020 Base Plans:</p>	13.244	11.836	11.625	0.000	11.625

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624349 / <i>Materials Technology for Sustainment</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Develop best practices to ensure repeatability of advanced materials and processes technology to repair and extend the life of Air Force systems. Further refine through demonstration the understanding of material durability and repair limits for emerging Air Force systems. Advance the analysis and development of improved lifecycle prediction test methods and techniques to understand effects of service environments, corrosion, residual stresses, and material processes on structural and functional materials. Continue to improve the service life of advanced materials, processes and designs for improved repair and maintainability and life cycle cost of outer-moldline coatings, access panel treatments, and multifunctional systems. Further advance specialty material affordability technologies and processes to reduce maintenance costs of specialty materials.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.066 million. Funding increased due to added emphasis in predictive analysis for residual stress and specialty materials.</p>					
<p>Title: Failure Analysis Technologies</p> <p>Description: Develop support capabilities, information, and processes to resolve materials problems and provide electronic and structural failure analysis of components.</p> <p>FY 2019 Plans: Continue to perform and increase efficiency of quick response failure analyses and materials investigations. Continue to develop and investigate improved analysis techniques to determine and prevent root cause materials failure/degradation, provide advanced materials to ensure warfighter system availability and safety of flight. Refine development of functional materials failure analysis capabilities. Continue to analyze and validate advanced electrostatic discharge protection technologies and procedures for emerging avionics subsystems. Continue the transition of advanced test and characterization methods for analyzing electrical and structural failures of emerging materials. Continue development and demonstrate new, more durable materials and protection for high power wiring technologies for Air Force weapon systems. Continue research, development and characterization of advanced materials.</p> <p>FY 2020 Base Plans: Continue to perform and increase efficiency of quick response failure analyses and materials investigations. Further the development and investigate improved analysis techniques to determine and prevent root cause materials failure/degradation. Continue to develop and provide advanced materials and processing solutions</p>	18.596	17.754	17.853	0.000	17.853

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624349 / <i>Materials Technology for Sustainment</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
to ensure warfighter system availability and safety of flight. Refine development of functional materials failure analysis capabilities. Continue to analyze and validate advanced electrostatic discharge protection technologies and procedures for emerging avionics subsystems. Transition advanced test and characterization methods for analyzing electrical and structural failures of emerging materials. Continue development and demonstrate new, more durable materials and protection for high power wiring technologies, and advanced materials. FY 2020 OCO Plans: Not Applicable FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.099 million. Justification for the increase is described in the plans above.					
Accomplishments/Planned Programs Subtotals	45.529	45.523	45.500	0.000	45.500

	FY 2018	FY 2019
Congressional Add: Program Increase - Coatings FY 2018 Accomplishments: Conducted Congressionally directed efforts. FY 2019 Plans: Not Applicable	4.914	0.000
Congressional Add: Program Increase - Coating Technologies FY 2018 Accomplishments: Not applicable FY 2019 Plans: Conduct Congressionally directed efforts.	0.000	10.000
Congressional Adds Subtotals	4.914	10.000

C. Other Program Funding Summary (\$ in Millions)

N/A
Remarks

D. Acquisition Strategy

Not Applicable.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602102F / <i>Materials</i>	Project (Number/Name) 624349 / <i>Materials Technology for Sustainment</i>

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force / BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	151.637	160.461	147.724	0.000	147.724	150.700	159.677	145.523	148.851	Continuing	Continuing
622401: <i>Structures</i>	-	52.025	43.415	41.817	0.000	41.817	45.563	47.591	49.437	50.666	Continuing	Continuing
622403: <i>Flight Controls and Pilot-Vehicle Interface</i>	-	29.130	40.402	49.297	0.000	49.297	49.717	55.003	36.761	37.632	Continuing	Continuing
622404: <i>Aeromechanics and Integration</i>	-	28.663	30.932	28.595	0.000	28.595	29.503	30.635	31.910	32.571	Continuing	Continuing
622405: <i>High Speed Systems Technology</i>	-	41.819	45.712	28.015	0.000	28.015	25.917	26.448	27.415	27.982	Continuing	Continuing

A. Mission Description and Budget Item Justification

This effort investigates, develops, and analyzes aerospace vehicle technologies in the three primary areas of structures, controls, and aerodynamics for legacy and future aerospace vehicles. Advanced structures concepts are explored and developed to exploit new materials, fabrication processes, and design techniques. Vehicle, inter-vehicle, and intra-vehicle control technologies are developed and simulated for aerospace vehicles. Advanced aerodynamic vehicle configurations are developed and analyzed through simulations, experiments, and multi-disciplinary analyses. Resulting technologies improve performance of existing and future manned/unmanned and remotely piloted air vehicles, sustained high speed, and space access vehicles. Improvements include, but are not limited to, reduced energy use by efficient air platform designs, use of lightweight composite structures, and improved sustainment methods based on the condition of the platform and sub-systems. Projects in this effort have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	124.678	130.547	140.859	0.000	140.859
Current President's Budget	151.637	160.461	147.724	0.000	147.724
Total Adjustments	26.959	29.914	6.865	0.000	6.865
• Congressional General Reductions	-0.054	-0.086			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	31.000	30.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-2.393	0.000			
• Other Adjustments	-1.594	0.000	6.865	0.000	6.865

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 622401: Structures

Congressional Add: *Program increase - structures*

Congressional Add Subtotals for Project: 622401

Project: 622403: Flight Controls and Pilot-Vehicle Interface

Congressional Add: *Program increase - human machine teaming*

Congressional Add: *Program increase - flight controls and pilot-vehicle interfaces*

Congressional Add Subtotals for Project: 622403

Project: 622405: High Speed Systems Technology

Congressional Add: *Program increase - high speed systems technology*

Congressional Add: *Program increase - hypersonic vehicle structures*

Congressional Add: *Program increase - hypersonic research capability development*

Congressional Add: *Program increase - hypersonic wind tunnels*

Congressional Add Subtotals for Project: 622405

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	9.846	0.000
Congressional Add Subtotals for Project: 622401	9.846	0.000
	0.000	4.000
	0.000	5.000
Congressional Add Subtotals for Project: 622403	0.000	9.000
	5.908	6.000
	9.846	10.000
	4.923	0.000
	0.000	5.000
Congressional Add Subtotals for Project: 622405	20.677	21.000
Congressional Add Totals for all Projects	30.523	30.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>
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Change Summary Explanation

Decrease in FY 2018 of \$1.594 million in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

Increase in FY 2020 of \$6.865 million is due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602201F / Aerospace Vehicle Technologies				Project (Number/Name) 622401 / Structures			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622401: Structures	-	52.025	43.415	41.817	0.000	41.817	45.563	47.591	49.437	50.666	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops advanced structures concepts to exploit new materials and fabrication processes and investigates new concepts and design techniques. New structural concepts include low cost design and fabrication techniques, incorporating subsystem hardware items and adaptive mechanisms into the aerospace structures and/or skin of the platform.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Aircraft Service Life Technologies</p> <p>Description: Develop an economic service life analysis capability comprised of analysis tools, methodologies, and structural health monitoring technologies.</p> <p>FY 2019 Plans: Continue methods for achieving lifing credit in advanced & enhanced metallic airframe components to extend structural life. Continue demonstration of Aircraft Digital Twin models and tools on legacy fleet aircraft. Initiate development of impact damage analysis criteria and methods for advanced composite structures.</p> <p>FY 2020 Plans: Complete methods for achieving lifing credit in advanced & enhanced metallic airframe components to extend structural life. Continue demonstration of Aircraft Digital Twin models and tools on legacy fleet aircraft. Complete development of impact damage analysis criteria and methods for advanced composite structures. Initiate lifing methods for durability and damage tolerance of aging composite structures on legacy fleet aircraft. Initiate development of digital maintenance models and virtual and augment reality maintenance tools.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$7.528 million. Funding decreased due to completion of efforts in structural lifing methods for composite and metallic structures in early FY 2020 and transition to composite structures life extension validation tests.</p>	21.992	22.637	15.109
<p>Title: Vehicle Design Technologies</p> <p>Description: Develop methodologies to reduce the cost and time involved from design to full-scale testing of structural concepts and aerospace systems.</p> <p>FY 2019 Plans:</p>	12.362	12.724	13.739

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622401 / <i>Structures</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Continue the development of advanced high fidelity aircraft design analysis tools. Complete parametric modeling methods for integrated multi-discipline collaborative design. Complete the development of design methods for low cost attributable aircraft concepts. Complete the evaluation of control effector concepts for supersonic tailless aircraft. Continue the development of integrating cost, mission effectiveness, and affordable manufacturing methods into the aircraft design analysis tools. Initiate the development of control effector designs for supersonic tailless aircraft.</p> <p>FY 2020 Plans: Continue the development of advanced high fidelity aircraft design analysis tools. Continue the development of integrating cost, mission effectiveness, and affordable manufacturing methods into aircraft design analysis tools (completing methods on low cost attributable aircraft concepts in FY 2020 and starting methods for other aircraft systems). Continue the development of control effector designs for supersonic tailless aircraft. Initiate new design techniques to quantify and trade risk impacts against performance in aircraft designs.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.015 million. Funding increased due to additional development in aerospace vehicle design tool methods.</p>				
<p>Title: Structural Concepts</p> <p>Description: Develop design methods, processes, and lightweight, adaptive, and multifunctional structural concepts to capitalize on new materials, multi-role considerations, and technology integration into aircraft systems.</p> <p>FY 2019 Plans: Complete innovative energy efficient conformal load bearing antenna structural concepts. Continue development and verification of low cost attributable airframe concepts and manufacturing methods. Continue development of lightweight aircraft structural concepts to support Air Superiority 2030 and Advanced Mobility requirements. Initiate development of innovative structural design methods to dramatically reduce weight and complexity of aircraft structures. Initiate the development of fail-safe technologies for bonded unitized composite structures applicable to Mobility aircraft.</p> <p>FY 2020 Plans: Continue development and verification of low cost attributable airframe concepts and manufacturing methods (completing wing structure developments in FY 2020 and starting concepts for the fuselage and complete airframe). Complete development of lightweight aircraft structural concepts to support Air Superiority 2030 and Advanced Mobility requirements. Continue development of innovative structural design methods to dramatically reduce weight and complexity of aircraft structures. Continue the</p>		7.825	8.054	12.969

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622401 / <i>Structures</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
development of fail-safe technologies for bonded unitized composite structures applicable to Mobility aircraft (completing durability requirements in FY 2020 and starting structural life component tests).			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$4.915 million. Funding increased due to additional emphasis in development of low cost structures in this major effort to support low cost attritable aircraft development.			
Accomplishments/Planned Programs Subtotals	42.179	43.415	41.817

	FY 2018	FY 2019
<i>Congressional Add:</i> Program increase - structures	9.846	0.000
<i>FY 2018 Accomplishments:</i> Conducted Congressionally directed efforts		
<i>FY 2019 Plans:</i> Not Applicable		
Congressional Adds Subtotals	9.846	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not Applicable.

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>				Project (Number/Name) 622403 / <i>Flight Controls and Pilot-Vehicle Interface</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622403: <i>Flight Controls and Pilot-Vehicle Interface</i>	-	29.130	40.402	49.297	0.000	49.297	49.717	55.003	36.761	37.632	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops technologies that enable maximum affordable capability from manned, remotely-piloted and autonomous aerospace vehicles. Advanced control technologies are developed for maximum vehicle performance throughout the flight envelope and simulated in virtual environments. Resulting technologies contribute significantly towards the development of reliable autonomous or remotely piloted air vehicles, hypersonic aircraft, and extended-life legacy aircraft.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Advanced Flight Controls Technologies</p> <p>Description: Develop technologies for advanced control-enabled capabilities, including flight controls, components, integrated vehicle management systems and software and system certification techniques for both manned/unmanned and remotely piloted aircraft.</p> <p>FY 2019 Plans: Continue the development, demonstration, and assessment of advanced flight control mechanization technologies for trusted and certifiable operations under adverse and contested environments. Continue the development of survivable and health-adaptive control system architecture. Complete the development of advanced automation capabilities for mobility aircraft and transition to advanced development. Continue the development of trusted autonomy approach, integrating certification processes and autonomy development.</p> <p>FY 2020 Plans: Continue the development, demonstration, and assessment of advanced flight control mechanization technologies for trusted and certifiable operations under adverse and contested environments. Complete the development of survivable and health-adaptive control system architecture. Continue the development of trusted autonomy approach, integrating certification processes and autonomy development.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.406 million. Justification for the decrease is described in the plans above.</p>	6.676	7.196	6.790
<p>Title: Manned and Unmanned Teaming Technologies</p> <p>Description: Develop technology for flight control systems that will permit safe interoperability between manned and remotely piloted aircraft and effective teaming in adverse and contested environments.</p>	17.345	18.699	17.644

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622403 / <i>Flight Controls and Pilot-Vehicle Interface</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p><i>FY 2019 Plans:</i> Continue development, demonstration, and assessment of advanced control automation techniques. Continue the development of mixed initiative control techniques for teams of remotely piloted aircraft and/or manned-unmanned teams in contested, dynamic mission environments, as well as for the integration of unmanned systems into controlled airspace and airbase operations. Continue the development of robust, affordable Unmanned Aircraft System (UAS) operations in a terminal airspace environment. Continue the development of autonomous behaviors for safe, loyal wingman.</p> <p><i>FY 2020 Plans:</i> Continue development, demonstration, and assessment of advanced control automation techniques. Continue the development of mixed initiative control techniques for teams of remotely piloted aircraft and/or manned-unmanned teams in contested, dynamic mission environments, as well as for the integration of unmanned systems into controlled airspace and airbase operations. Continue the development of robust, affordable Unmanned Air Systems (UAS) operations in a terminal airspace environment. Complete the development of autonomous behaviors for safe, loyal wingman. Initiate the development of autonomous behaviors for safe, effective manned-unmanned teams.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$1.055 million. Funding decreased due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.</p>			
<p><i>Title:</i> Flight Controls Technologies Modeling and Simulation</p> <p><i>Description:</i> Develop tools and methods for capitalizing on simulation-based research and development of future aerospace vehicles.</p> <p><i>FY 2019 Plans:</i> Continue modeling and simulation efforts to evaluate emerging autonomous and robust flight control technologies and concepts, as well as assess mission-level performance of integrated aerospace systems. Continue analyses of automated unmanned air systems and manned-unmanned teams in controlled airspace and airbase operations, as well as in adversarial mission environments. Continue trade studies of vehicle concepts for strike, mobility and reconnaissance. Continue manned-unmanned teaming evaluations. Continue development of autonomy for tactical aircraft operations.</p> <p><i>FY 2020 Plans:</i> Continue modeling and simulation efforts to evaluate emerging autonomous and robust flight control technologies and concepts, as well as assess mission-level performance of integrated aerospace systems. Complete analyses of automated unmanned air systems and manned-unmanned teams in controlled airspace and airbase operations. Continue analyses of manned-unmanned teams in adversarial mission environments. Continue trade studies of vehicle concepts for strike, mobility and</p>	5.109	5.507	5.196

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019	
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622403 / <i>Flight Controls and Pilot-Vehicle Interface</i>	
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019
reconnaissance. Continue manned-unmanned teaming evaluations including rapid development of new capabilities. Complete development of autonomy for tactical aircraft operations.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.311 million. Justification for the decrease is described in the plans above.			
Title: Future AF Capabilities Applied Research		0.000	0.000
Description: Investigate, design, and develop science and technologies supporting future Air Force capabilities to provide compelling advantage to the warfighter. To the greatest extent practical, research efforts will utilize modeling and simulation and cross-discipline systems integration (For example: air and space vehicles, avionics, propulsion, materials, human performance, cybersecurity, command, control, communications, computer and intelligence, sensors, electronic warfare, and conventional/unconventional weapons).			19.667
The National Defense Strategy and Air Force Science and Technology 2030 Strategy will inform investments over the FYDP.			
FY 2019 Plans: In FY 2019, this work is performed under multiple projects and efforts within the following Air Force Science and Technology Programs: 0602102F, Materials; 0602201F, Aerospace Vehicle Technologies; 0602202F, Human Effectiveness Applied Research; 0602203F, Aerospace Propulsion; 0602204F, Aerospace Sensors; 1206601F, Space Technology; 0602602F, Conventional Munitions; 0602605F, Directed Energy Technology; and 0602788F, Dominant Information Science and Methods.			
FY 2020 Plans: Continue to investigate and mature science and technology that enables future warfighting concepts to provide leap-ahead capabilities. The National Defense Strategy and Air Force Science and Technology 2030 Strategy focus this science and technology toward, but not limited to, the following capabilities: 1) global persistent awareness; 2) resilient information sharing; 3) rapid, effective decision-making; 4) complexity, unpredictability, and mass; and 5) speed and reach of disruption and lethality.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$19.667 million. Funding increased due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.			
Accomplishments/Planned Programs Subtotals		29.130	31.402
			49.297
		FY 2018	FY 2019
Congressional Add: Program increase - human machine teaming		0.000	4.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622403 / <i>Flight Controls and Pilot-Vehicle Interface</i>
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	FY 2018	FY 2019
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts.		
Congressional Add: Program increase - flight controls and pilot-vehicle interfaces	0.000	5.000
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts.		
Congressional Adds Subtotals	0.000	9.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not Applicable.

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622404 / <i>Aeromechanics and Integration</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622404: <i>Aeromechanics and Integration</i>	-	28.663	30.932	28.595	0.000	28.595	29.503	30.635	31.910	32.571	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops aerodynamic configurations of a broad range of revolutionary, affordable aerospace vehicles. It matures and applies modeling and numerical simulation methods for fast and affordable aerodynamics prediction and integrates and demonstrates multi-disciplinary advances in airframe, propulsion, weapon and air vehicle control integration.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Aerodynamic Systems Technologies</p> <p>Description: Develop aerodynamic assessment prediction methods centered on expanding the design capabilities of future air vehicles.</p> <p>FY 2019 Plans: Continue development and assessment of low cost attributable Unmanned Aircraft Vehicle (UAV) concepts. Complete assessment of efficient airfoil flow control and distributed propulsion concepts. Continue design assessments of distributed propulsion concepts for next generation Mobility. Initiate the development of a high fidelity aerodynamic analysis tool for the design of laser turrets applicable to Air Superiority 2030 requirements.</p> <p>FY 2020 Plans: Continue development and assessment of low cost attributable UAV concepts. Continue design assessments of distributed propulsion concepts for next generation Mobility. Continue the development of a high fidelity aerodynamic analysis tool for the design of laser turrets applicable to Air Superiority 2030 requirements (completing a sub-scale design in FY 2020 and starting a sub-scale build and full-scale turret design). Initiate the assessment and development of incorporating active flow control techniques into advanced design to enable new aircraft configurations.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$1.774 million. Funding decreased due to reduced emphasis in the high fidelity aerodynamic analysis for laser turret design and additional needs in the Aircraft Integration Technologies effort.</p>	7.582	8.181	6.407
<p>Title: Next Generation Aerodynamic Technologies</p> <p>Description: Develop and assess technologies for the next generation of multi-role large aircraft.</p> <p>FY 2019 Plans:</p>	9.137	9.860	7.087

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622404 / <i>Aeromechanics and Integration</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Complete development of high fidelity aerodynamic analysis and method development for future Air Superiority 2030. Complete development of practical laminar flow technologies for highly swept wings. Continue next generation tanker maturation and assess promising configurations in high and low speed wind tunnels. Complete distributed embedded propulsion wind tunnel test. Initiate wind tunnel tests of practical laminar flow treatments and coatings for highly swept wings applicable to Mobility applications.</p> <p>FY 2020 Plans: Continue next generation tanker maturation and assess promising configurations in high and low speed wind tunnels. Continue wind tunnel tests of practical laminar flow treatments and coatings for highly swept wings applicable to Mobility applications. Initiate the design of a small, pod-mounted tactical air refueling boom for future Mobility applications. Initiate the development of advanced high fidelity aerodynamic analysis tools for aircraft conceptual design.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$2.773 million. Funding decreased due to reduced emphasis in Next Generation Aerodynamic Technologies with the completion of the high fidelity aerodynamic analysis for Air Superiority 2030 and completion of the laminar flow technologies in 2019.</p>				
<p>Title: Aircraft Integration Technologies</p> <p>Description: Develop enabling technologies to allow efficient and effective integration of propulsion, weapons, and subsystems into current and future air vehicles.</p> <p>FY 2019 Plans: Continue development of advanced kinetic and directed energy weapons integration technologies for future air superiority. Complete the design of an integrated full flow path demonstration of a medium bypass embedded engine for next generation mobility. Initiate integrated full flow path demonstration of a medium bypass embedded engine for next generation mobility. Initiate propulsion integrations component wind tunnels tests for Air Superiority 2030 requirements.</p> <p>FY 2020 Plans: Continue development of advanced kinetic and directed energy weapons integration technologies for Air Superiority 2030. Continue integrated full flow path demonstration of a medium bypass embedded engine for next generation mobility, completing the system requirements definition in FY 2020 and starting the full flow bath demonstration design. Continue propulsion integrations component wind tunnels tests for Air Superiority 2030 requirements.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$2.210 million. Funding increased due to additional resources required for the design phase of integrated full flow path demonstration of a medium bypass embedded engine.</p>		11.944	12.891	15.101
Accomplishments/Planned Programs Subtotals		28.663	30.932	28.595

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622404 / <i>Aeromechanics and Integration</i>

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not Applicable.

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>				Project (Number/Name) 622405 / <i>High Speed Systems Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622405: <i>High Speed Systems Technology</i>	-	41.819	45.712	28.015	0.000	28.015	25.917	26.448	27.415	27.982	Continuing	Continuing

A. Mission Description and Budget Item Justification

This effort investigates, analyzes, and develops high speed/hypersonic aerospace vehicle technologies. Advanced high temperature structures concepts are explored and developed to exploit new materials, fabrication processes, and design techniques. Advanced aerodynamic vehicle configurations are developed and analyzed through simulations, experiments, and multi-disciplinary analyses. Advanced flight control technologies are developed and simulated for hypersonic vehicles. These technologies will enable future high speed; weapons, intelligence, surveillance, and reconnaissance systems; and space access vehicles.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: High Speed Systems Technology	12.291	14.366	16.286
Description: Develop design analysis methods and technologies for high speed systems in for extreme flight conditions.			
FY 2019 Plans: Continue maturation of innovative structural concepts for high speed/hypersonic air vehicles. Continue development of analytical methods for predicting structural response needed for design and evaluation of hot primary structure for hypersonic vehicles. Continue to assess the impact of path dependent structural behavior on the service life prediction for hot structures encountering extreme environments. Continue to develop and integrate model uncertainty methods into multi-disciplinary simulations and quantify its impact on the structural margin. Continue development of structural analysis methods and technology for hot structure concepts under extreme environment loading conditions. Continue the assessment of the aerospace community to quantify the structural margins for extreme environment hot structure through experimental validation of ground test articles. Continue development of structural life prediction methodology for extreme environment structures and thermal protection systems. Initiate development on novel designs and demonstration of integrated hot structures for hypersonic reusable air platforms.			
FY 2020 Plans: Continue maturation of innovative structural concepts for high speed/hypersonic air vehicles. Continue development of analytical methods for predicting structural response needed for design and evaluation of hot primary structure for hypersonic vehicles. Continue to assess the impact of path dependent structural behavior on the service life prediction for hot structures encountering extreme environments. Continue to develop and integrate model uncertainty methods into multi-disciplinary simulations and quantify its impact on the structural margin. Continue development of structural analysis methods and technology for hot structure concepts under extreme environment loading conditions. Continue the assessment of the aerospace community to quantify the structural margins for extreme environment hot structure through experimental validation of ground test articles. Continue			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622405 / <i>High Speed Systems Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>development of structural life prediction methodology for extreme environment structures and thermal protection systems. Continue development on novel designs and demonstration of integrated hot structures for hypersonic reusable air platforms.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.920 million. Justification for the increase is to focus activities in design and life prediction on a proposed flight demonstration in FY 2022.</p>				
<p>Title: High Speed Vehicle Aeromechanics and Integration</p> <p>Description: Develop new and improved components, concepts, and designs for sustained flight of high-speed/hypersonic expendable and re-useable vehicles. Conduct analyses of high speed/hypersonic vehicles to enable revolutionary capabilities.</p> <p>FY 2019 Plans: Complete the manufacturing of flight vehicle hardware for Hypersonic International Flight Research Experimentation 5c. Continue to mature critical technologies for high speed/hypersonic flight. Continue development of design/analysis techniques/ tools and experimental approaches to enable enhanced high-speed air induction system starting, operability, and performance for propulsion integration concepts over a wide range of flight conditions. Continue development of high speed system concepts that provide revolutionary capabilities. Continue investigation of aeromechanic technologies to reduced drag and enable robust stability and control at low dynamic pressure flight conditions. Continue efforts to characterize high-speed phenomena and develop and validate fundamental high- speed technologies through experimental testing. Continue assessment of mission-level effectiveness and refinement of definition of preferred high speed weapon alternatives and limited life hypersonic intelligence, surveillance, and reconnaissance vehicles. Continue assessment of campaign-level benefits of preferred high speed weapon alternatives.</p> <p>FY 2020 Plans: Continue to mature critical technologies for high speed/ hypersonic flight. Continue development of design/analysis techniques/ tools and experimental approaches to enable enhanced high-speed air induction system starting, operability, and performance for propulsion integration concepts over a wide range of flight conditions. Continue development of high speed system concepts that provide revolutionary capabilities. Continue investigation of aeromechanic technologies to reduced drag and enable robust stability and control at low dynamic pressure flight conditions. Continue efforts to characterize high-speed phenomena and develop and validate fundamental high- speed technologies through experimental testing. Continue assessment of mission-level effectiveness and refinement of definition of preferred high speed weapon alternatives and limited life hypersonic intelligence, surveillance, and reconnaissance vehicles. Continue assessment of campaign-level benefits of preferred high speed weapon alternatives.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>		8.851	10.346	11.729

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622405 / <i>High Speed Systems Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$1.383 million. Funding increased due to additional vehicle design and propulsion integration activities to support proposed flight demonstration in FY 2022.				
Accomplishments/Planned Programs Subtotals		21.142	24.712	28.015
		FY 2018	FY 2019	
Congressional Add: Program increase - high speed systems technology		5.908	6.000	
FY 2018 Accomplishments: Conducted Congressionally directed efforts				
FY 2019 Plans: Conduct Congressionally directed efforts				
Congressional Add: Program increase - hypersonic vehicle structures		9.846	10.000	
FY 2018 Accomplishments: Conducted Congressionally directed efforts				
FY 2019 Plans: Conduct Congressionally directed efforts				
Congressional Add: Program increase - hypersonic research capability development		4.923	0.000	
FY 2018 Accomplishments: Conducted Congressionally directed efforts				
FY 2019 Plans: Not Applicable				
Congressional Add: Program increase - hypersonic wind tunnels		0.000	5.000	
FY 2018 Accomplishments: Not Applicable				
FY 2019 Plans: Conduct Congressionally directed efforts.				
	Congressional Adds Subtotals	20.677	21.000	
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				
N/A				
D. Acquisition Strategy				
Not Applicable				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602201F / <i>Aerospace Vehicle Technologies</i>	Project (Number/Name) 622405 / <i>High Speed Systems Technology</i>

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	0.000	126.542	119.018	131.795	0.000	131.795	131.809	137.542	122.565	125.402	Continuing	Continuing
621123: <i>Learning and Operational Readiness</i>	0.000	41.340	22.440	22.495	0.000	22.495	21.649	22.814	23.702	24.012	Continuing	Continuing
625328: <i>Human Dynamics Evaluation</i>	0.000	22.987	26.068	51.449	0.000	51.449	52.265	53.438	34.814	35.620	Continuing	Continuing
625329: <i>Sensory Evaluation and Decision Science</i>	0.000	33.085	36.687	30.726	0.000	30.726	31.259	32.682	33.957	34.392	Continuing	Continuing
627757: <i>Bioeffects</i>	0.000	29.130	33.823	27.125	0.000	27.125	26.636	28.608	30.092	31.378	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program conducts applied research in the area of airmen training, airmen system interfaces, bioeffects, and understanding and shaping adversarial behavior. The Learning and Operational Readiness project conducts research to measure, accelerate, and expand the cognitive skills necessary to improve airmen training and mission performance. The Human Dynamics Evaluation project conducts research to advance machine intelligence and operator-aiding technologies by developing and applying airman-focused research for advanced intelligence, surveillance, and reconnaissance (ISR) capabilities and detecting and exploiting human signatures. The Sensory Evaluation and Decision Science project conducts research to revolutionize the manner in which airmen optimize the capabilities of Air Force systems, including remotely piloted aircraft (RPA) and adaptive teams of airmen and machines. The Bioeffects project conducts research on the effects of human exposure to electromagnetic (EM) energy (radio frequency to optical), scalable directed energy weapons, and non-lethal weapons. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	108.784	112.518	122.392	0.000	122.392
Current President's Budget	126.542	119.018	131.795	0.000	131.795
Total Adjustments	17.758	6.500	9.403	0.000	9.403
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	24.500	6.500			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-2.391	0.000			
• Other Adjustments	-4.351	0.000	9.403	0.000	9.403

Congressional Add Details (\$ in Millions, and Includes General Reductions)

	FY 2018	FY 2019
Project: 621123: <i>Learning and Operational Readiness</i>		
Congressional Add: <i>Program Increase - learning and operational readiness</i>	19.150	0.000
Congressional Add Subtotals for Project: 621123	19.150	0.000
Project: 625328: <i>Human Dynamics Evaluation</i>		
Congressional Add: <i>Program Increase - Warfighter physiology program</i>	0.000	1.500
Congressional Add Subtotals for Project: 625328	0.000	1.500
Project: 625329: <i>Sensory Evaluation and Decision Science</i>		
Congressional Add: <i>Program Increase - Hypoxia research</i>	4.910	5.000
Congressional Add Subtotals for Project: 625329	4.910	5.000
Congressional Add Totals for all Projects	24.060	6.500

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

Increase in FY 2020 due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 621123 / <i>Learning and Operational Readiness</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
621123: <i>Learning and Operational Readiness</i>	0.000	41.340	22.440	22.495	0.000	22.495	21.649	22.814	23.702	24.012	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research to measure, accelerate, and expand the cognitive skills necessary to improve airmen training and mission performance. Research is conducted in two focus areas: continuous learning and cognitive modeling. The continuous learning effort creates live, virtual, and constructive (LVC) environments for use in developing revolutionary simulation technologies to increase training capabilities and enhance training effectiveness and efficiency by using learning theory to improve military training and mission performance. Cognitive modeling creates realistic models and simulations of human behavior to advance the understanding of how airmen perform complex tasks.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Continuous Learning</p> <p>Description: Research enhances distributed mission operations (DMO) and LVC environments and identifies technology requirements for training in live and immersive environments. Continuous learning strategies improve mission training, command and control (C2), intelligence, surveillance and reconnaissance (ISR), and cyber missions.</p> <p>FY 2019 Plans: Grow persistent readiness assessment and tracking capabilities for optimized airman machine teaming. Establish objective training performance metrics. Continue to develop 5th Gen Cross Domain solution prototypes. Investigate integrated simulations of secure adaptive environments and execute training research studies within multi-domain command and control.</p> <p>FY 2020 Plans: Initiate validation of objective performance metrics in operationally relevant testbeds. Mature personalized learning technologies. Begin training scenario development and simulated mission rehearsals with focus on contested and degraded operational environments. Execute integrated multi-domain training evaluations to assess modeling and simulation capabilities and limitations. Begin studies to evaluate an optimized mix of live, synthetic, and blended training technologies and architecture standards to determine standards for proficiency based training and readiness assessments.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.028 million. Justification for the decrease is described in the plans above.</p>	18.158	13.733	13.705
<p>Title: Cognitive Modeling</p> <p>Description: Research explores application of cognitive science for performance improvement by enhancing training in mission-relevant environments (e.g., flight simulators, multi-domain operations).</p>	4.032	8.707	8.790

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 621123 / <i>Learning and Operational Readiness</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p><i>FY 2019 Plans:</i> Transition fatigue models for mobility operations. Demonstrate time-savings for mission planning using model-based processes. Integrate retention-based scheduling system for training into operational learning management system. Demonstrate prototype trainable agent for multi-domain operations.</p> <p><i>FY 2020 Plans:</i> Initiate research to extend fatigue models to unmanned aerial vehicles (UAV) and special operations. Begin research to generalize model-based mission planning capabilities to multi-domain command & control (C2) operational planning. Demonstrate multiscale models for real-time cognitive load estimation and prediction in operationally relevant environments. Demonstrate predictive models of toxin-induced cognitive and performance decrements in a laboratory environment. Mature trainable agent research to integrate machine learning to acquire knowledge from operational data. Transition retention-based scheduling system for training.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.083 million. Justification for the increase is described in the plans above.</p>			
Accomplishments/Planned Programs Subtotals	22.190	22.440	22.495

	FY 2018	FY 2019
<i>Congressional Add:</i> Program Increase - learning and operational readiness	19.150	0.000
<i>FY 2018 Accomplishments:</i> Conducted Congressionally directed effort		
<i>FY 2019 Plans:</i> Not applicable		
Congressional Adds Subtotals	19.150	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

None

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>				Project (Number/Name) 625328 / <i>Human Dynamics Evaluation</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625328: <i>Human Dynamics Evaluation</i>	0.000	22.987	26.068	51.449	0.000	51.449	52.265	53.438	34.814	35.620	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research to advance machine intelligence, information operations, operator-aiding technologies for advanced and multi-domain integrated intelligence, surveillance and reconnaissance (ISR) capabilities, and Airman bioscience protection technologies. Research is focused in the following areas: human analyst augmentation, human trust and interaction, human signatures, and molecular bioeffects. The human analyst augmentation area develops, integrates, and evaluates human-centric analyst technology to develop cognitive systems engineering solutions for airman data overload, work integration, and mission performance, enhancing operationally effective ISR for the Air Force. This area also includes research to enable and enhance airman-machine teaming for distributed multi-domain operations. The human trust and interaction area seeks to advance human language technologies to benefit military linguists and analysts as well as to understand, quantify, and calibrate trust factors influencing airman interaction with autonomous systems that can be applied to airman-machine teaming in future weapon systems. The human signatures area develops and applies Science & Technology (S&T) to detect and exploit a variety of human-centered signatures, including behavioral and anthropometric aspects of existing and emerging adversaries as well as bio and molecular signatures of airman performance. The molecular bioeffects area conducts research to protect Airmen from toxic chemicals and materials to include nanomaterials and other advanced development materials and to discover novel biomarkers and molecular mechanisms to support personalized training, performance and protection of Airmen cognitive and physical performance using advanced sense, assess and augment technologies.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Future AF Capabilities Applied Research	0.000	0.000	19.666
Description: Investigate, design, and develop science and technologies supporting future Air Force capabilities to provide compelling advantage to the warfighter. To the greatest extent practical, research efforts will utilize modeling and simulation and cross-discipline systems integration (For example: air and space vehicles, avionics, propulsion, materials, human performance, cybersecurity, command, control, communications, computer and intelligence, sensors, electronic warfare, and conventional/unconventional weapons).			
The National Defense Strategy and Air Force Science and Technology 2030 Strategy will inform investments over the FYDP.			
FY 2019 Plans: In FY 2019, this work is performed under multiple projects and efforts within the following Air Force Science and Technology Programs: 0602102F, Materials; 0602201F, Aerospace Vehicle Technologies; 0602202F, Human Effectiveness Applied			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 625328 / <i>Human Dynamics Evaluation</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Research; 0602203F, Aerospace Propulsion; 0602204F, Aerospace Sensors; 1206601F, Space Technology; 0602602F, Conventional Munitions; 0602605F, Directed Energy Technology; and 0602788F, Dominant Information Science and Methods.</p> <p>FY 2020 Plans: Continue to investigate and mature science and technology that enables future warfighting concepts to provide leap-ahead capabilities. The National Defense Strategy and Air Force Science and Technology 2030 Strategy focus this science and technology toward, but not limited to, the following capabilities: 1) global persistent awareness; 2) resilient information sharing; 3) rapid, effective decision-making; 4) complexity, unpredictability, and mass; and 5) speed and reach of disruption and lethality.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$19.666 million. Funding increased due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.</p>				
<p>Title: Human Analyst Augmentation</p> <p>Description: Conduct research to enhance human components of intelligence, surveillance and reconnaissance (ISR). Develop ability to improve human analytic efficiency and effectiveness with fewer personnel and in increasingly complex mission space. Develop the ability to improve human cognitive performance of the ISR weapon system through improved data exploitation and intelligence content synthesis. Conduct research to optimize multi-domain ISR airman performance.</p> <p>FY 2019 Plans: Further investigate cognitive mechanisms that underlie analyst's sense making capabilities and develop methodologies to use autonomous agents to assist in the process.</p> <p>FY 2020 Plans: Develop fundamental design principles and theories in human-machine teaming, human performance, psychological processes, and physiological indicators focused on systems analytics and multi-domain integrated concepts. Design and envision capabilities to improve analytic insight and reasoning, and integrated multi-domain planning and execution. Integrate threat detection, characterization, and tracking algorithms into human-machine teaming systems to improve decision making for multi-domain operational planners. Develop robust and dynamic synthetic intelligence mission data to stimulate, evaluate, and validate software tools for multi-domain operational planners.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.001 million. Justification for the decrease is described in the plans above.</p>		8.826	9.692	9.691
<p>Title: Human Trust and Interaction</p> <p>Description: Conduct research in cross-cultural communication and automated speech translation tools for Air Force missions. Conduct research to address important aspects of trust in airman-machine teams including investigating how an airman</p>		7.618	8.785	8.784

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 625328 / <i>Human Dynamics Evaluation</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>knows an autonomous or semiautonomous system is safe to use and whether the system, data, conclusions, and decision recommendations can be trusted.</p> <p>FY 2019 Plans: Develop initial transparency and trust guidelines for application to semiautonomous vehicles and autonomous agents for analysts. Investigate techniques for translating text to images and images to text.</p> <p>FY 2020 Plans: Advance and mature human machine teaming trust and transparency standards to semi-autonomous and autonomous applications. Investigate extending translation and natural language processing research to multimedia information extraction.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.001 million. Justification for the decrease is described in the plans above.</p>				
<p>Title: Human Signatures</p> <p>Description: Develop databases of human motion and features collected from air/space platforms. Identify human threat signatures across diverse populations for intelligence, surveillance and reconnaissance (ISR) and force protection applications. Develop and exploit nano, bio, and molecular signatures of airman performance. Develop man-machine interfaces via wearable, affordable, and real-time platforms to assess airman performance.</p> <p>FY 2019 Plans: Develop methodologies for air quality and physiological monitoring of personnel using machine learning techniques. Develop algorithms to characterize human detections from air based sensors.</p> <p>FY 2020 Plans: Continue to develop methodologies for air quality and physiological monitoring of personnel using machine learning techniques. Continue to develop algorithms to characterize human detections from air based sensors. Research and develop sensors that detect volatile organic compounds and novel biomarkers to determine Airman readiness.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable</p>		6.543	6.091	6.091
<p>Title: Molecular Bioeffects</p> <p>Description: Protect airman from toxic chemicals and materials and enhance performance capability under demanding training and mission activities through molecular bioscience research. Investigate the underlying molecular-biological mechanisms contributing to airman physical and cognitive performance optimization.</p>		0.000	0.000	7.217

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 625328 / <i>Human Dynamics Evaluation</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>FY 2019 Plans: For FY 2019 and prior, this work is performed under Project 627757, Bioeffects, Molecular Bioeffects effort.</p> <p>FY 2020 Plans: Study the unknown physiological events occurring in pilots using omics technology (i.e., genomics, proteomics, and metabolomics) to predict Airman physical and cognitive states in that operational environment. Refine the development of an Air Force Specific In vitro Screen to enable rapid and accurate assessment of potentially toxic chemicals and materials including nanoparticles. Identify a potential safe and effective fatigue counter measures to improve Airmen performance in physically or mentally intensive operational environment. Conduct studies to predict how networks that form the whole of living organisms will change over time and under varying operationally relevant conditions.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$7.217 million. Funding increased due to work transferred from Project 627757, Bioeffects, Molecular Bioeffects effort.</p>			
Accomplishments/Planned Programs Subtotals	22.987	24.568	51.449

	FY 2018	FY 2019
Congressional Add: Program Increase - Warfighter physiology program	0.000	1.500
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts		
Congressional Adds Subtotals	0.000	1.500

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>				Project (Number/Name) 625329 / <i>Sensory Evaluation and Decision Science</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625329: <i>Sensory Evaluation and Decision Science</i>	0.000	33.085	36.687	30.726	0.000	30.726	31.259	32.682	33.957	34.392	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research to revolutionize the manner in which airmen optimize the capabilities of Air Force systems, including remotely piloted aircraft (RPA) and adaptive teams of airmen and machines. Research optimizes airman situational awareness and cognitive performance, improves the airman-machine interface, and seamlessly integrates warfighters with their weapon systems across air, space, and cyber domains. Research is conducted in four focus areas: applied neuroscience; human role in semiautonomous systems; battlespace visualization; and battlespace acoustics. The applied neuroscience area develops technologies to enhance airman-airman and airman-machine collaborations and system interactions in distributed decision-making environments. The human role in semiautonomous systems area develops new control/display concepts and technologies to optimize Air Force platform capabilities. The battlespace visualization area advances the science and technology (S&T) associated with collecting, optimizing, displaying, and assimilating sensory information to enhance warfighter decision-making. The battlespace acoustics area researches human-human and human-machine communications to exploit the use of voice and acoustic data in collaborative, net-centric environments while accounting for the effects of acoustic propagation.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Applied Neuroscience	12.161	14.634	14.211
Description: Develop technologies to enhance Airman performance and Airman-machine collaboration in high-stress decision-making environments. Conduct research to predict physiological impacts of extreme, dynamic environments.			
FY 2019 Plans: Continue to investigate and refine sensing and assessment technologies/capabilities for sustained and enhanced Airman performance in multiple operationally relevant environments including Airman-Machine Teaming scenarios and multi-domain operations. Validate applicability of biomarker sensor technologies use in operational environments. Continue to investigate augmentation techniques for physical and cognitive performance optimization and stress resilience and apply those techniques in operationally-relevant environments. Continue to explore utility of non-invasive peripheral nerve stimulation and closed-loop stimulation techniques to enhance cognitive performance. Complete development of the next generation aircraft injury exposure criteria for improved aircrew protection. Investigate multi-axis spinal injury modeling during aircraft ejection. Complete investigation of on-board oxygen generating system performance vulnerabilities affecting oxygen production. Complete the development for on-board oxygen generating system contamination database and susceptibility model. Research the development of the next generation of oxygen monitoring system.			
FY 2020 Plans:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 625329 / <i>Sensory Evaluation and Decision Science</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Validate sensing and assessment technologies/capabilities for sustained and enhanced Airman performance. Support the development of non-invasive off-body sensors for sensing biological and physiological indices of human performance. Continue to explore the utility of non-invasive peripheral nerve stimulation and other neuromodulation techniques to enhance cognitive performance. Identify the biological and physiological markers that predict enhanced cognitive performance in multiple field environments and under various stressors such as fatigue, high exertion, and oxygen deprived environments. Conduct bioinformatics studies on longitudinal data sets to inform cognitive performance augmentation strategies and refine customer decision tools. Research the novel biological and physical effects and safety implications of current and next-generation ejection seats and intense kinetic-energy scenarios involving human safety, to include the modeling & simulation of these effects on the human. Research the breathing and oxygenation systems for aircraft, investigate potential molecular and physiological sensing tools and techniques to ensure warfighter air quality safety and performance.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.423 million. Justification for the decrease is described in the plans above.</p>				
<p>Title: Human Role in Semiautonomous Systems</p> <p>Description: Research new Human-Machine Teaming (HMT) technologies and concepts (e.g., information portrayal, control devices, decision aiding algorithms and adaptive agents) for effective human-machine interaction and teamwork.</p> <p>FY 2019 Plans: Refine airman-system cooperative decision aids and interfaces that support distributed unmanned system control concepts in limited communication environments. Continue research and development of predictive, look-ahead tools for effects-based mission planning and execution. Continue research on real-time adaptive human-machine teaming/task allocation that includes examining workload and shared situation awareness metrics and the influence of machine aids on airmen problem solving, attention management and task prioritization. Continue research and development of airman-machine interface methods for real-time machine reasoning and negotiating processes.</p> <p>FY 2020 Plans: Examine novel HMT concepts and metrics in moderate-fidelity laboratory environments characterized by high-consequence, high-uncertainty missions. Examine the impact of novel HMT concepts, interfaces and agents on workload, shared situation awareness, performance, and trust using realistic laboratory environments which parallel operational challenges derived from Air Force operations, specifically focused on Multi-Domain Command & Control.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.205 million. Justification for the decrease is described in the plans above.</p>		5.579	6.224	6.019
<p>Title: Battlespace Visualization</p>		6.558	7.457	7.244

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 625329 / <i>Sensory Evaluation and Decision Science</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Description: Research the visualization, interaction and understanding of complex information to enhance warfighter decision making.</p> <p>FY 2019 Plans: Continue exploration of analytic strategies with machine learning techniques to achieve next-generation, automated, data exploitation capability, and develop visual interfaces to enhance decision making. Continue data analytics research focused on human visualization of complex data. Evaluate multi-domain operator system interfaces for integrated defensive and offensive operations. Refine models to predict visibility of objects viewed by humans under both unaided and aided conditions and explore multi-modal model integration. Continue to integrate visualizations of events and their influence on objectives and courses of action for command & control (C2) environments across the air, space and cyberspace domains.</p> <p>FY 2020 Plans: Select and evaluate analytic strategies with machine learning techniques to achieve next-generation, automated, data exploitation capability, and develop visual interfaces to enhance task performance and decision making. Develop and evaluate integration and tailoring of Explainable Artificial Intelligence (XAI) analytic methods with analytic visual interfaces. Continue data analytics research focused on human visualization of complex data. Test and modify multi-domain operator system interfaces for integrated defensive and offensive operations. Transition model of predicted visibility of objects viewed by humans under both unaided and aided conditions and develop multi-modal model integration. Test and evaluate visualizations of events and their influence on objectives and courses of action for C2 environments across the air, space and cyberspace domains. Conduct multi-sensory research and develop concepts for seamlessly integrating multiple interaction modes, such as visual, auditory, vestibular, and tactile, into integrated work aids.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.213 million. Justification for the decrease is described in the plans above.</p>			
<p>Title: Battlespace Acoustics</p> <p>Description: Conducts research on advanced auditory and communication technologies that mitigate effects of noise and enhance performance in operational environments.</p> <p>FY 2019 Plans: Continue to conduct research on auditory processing of complex, multi-source acoustic scenes and develop context-aware auditory displays for optimal delivery of real-time information from synthetic teammates, including verbal communication, spatial location and system state. Develop enhanced electro-acoustic characterization techniques for the prediction of auditory protection</p>	3.877	3.372	3.252

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 625329 / <i>Sensory Evaluation and Decision Science</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
and performance requirements. Examine and implement techniques for real-time augmentation of auditory reality. Enhance and refine biologically-inspired models of acoustic detection for special operations aviation.			
<i>FY 2020 Plans:</i> Conduct research on single sensor perception and multisensory interactions, focusing on multisensory integration and facilitation, as well as multisensory conflict for issues such as spatial disorientation. Determine optimal approaches for information presentation and communication management, incorporating both performance and preference metrics for enhanced decision making. Conduct research on speech identification and production, and develop interfaces and techniques to support effective human-human and human-machine communication. Evaluate emerging hearing enhancement and protection technologies to provide design guidelines for capabilities supporting future operations. Continue to enhance and refine models of acoustic detection for special operations aviation.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$0.120 million. Justification for the decrease is described in the plans above.			
Accomplishments/Planned Programs Subtotals	28.175	31.687	30.726

	FY 2018	FY 2019
<i>Congressional Add:</i> Program Increase - Hypoxia research	4.910	5.000
<i>FY 2018 Accomplishments:</i> Conducted Congressionally directed effort		
<i>FY 2019 Plans:</i> Conduct Congressionally directed efforts		
Congressional Adds Subtotals	4.910	5.000

C. Other Program Funding Summary (\$ in Millions)
N/A

Remarks

D. Acquisition Strategy
N/A

E. Performance Metrics
Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>				Project (Number/Name) 627757 / <i>Bioeffects</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
627757: <i>Bioeffects</i>	0.000	29.130	33.823	27.125	0.000	27.125	26.636	28.608	30.092	31.378	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project conducts applied research on the effects of human exposure to electromagnetic (EM) energy (direct current (DC) to radio frequency (RF) to optical), scalable directed energy weapons, and non-lethal weapons. This research addresses fundamental physical principles, as well as the psychophysical interaction between directed energy and the individual or groups of individuals. Research is divided into two core focus areas: optical radiation bioeffects and radio frequency radiation (RFR) bioeffects. Optical radiation bioeffects research enhances combat survivability and systems effectiveness through technologies that enable deployed forces to counter optical threats and exploit optical systems for offensive applications. The RFR bioeffects research investigates basic biological mechanisms of RFR, conducts theoretical and empirical dosimetry, conducts research of bioeffects from short and long-term exposures, develops methods to counter RFR threats, and performs research for exploitation of directed energy systems for offensive capabilities.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Optical Radiation Bioeffects	10.395	14.247	15.316
Description: Conduct laboratory experiments and field research on laser bioeffects, enabling military exploitation of laser technology while providing countermeasures for optical hazards/threats.			
FY 2019 Plans: Complete initial studies of alternate laser wavelength bioeffects for use in high-energy lasers. Incorporate glare vision effect models in national and Dept of Defense (DoD) standards for definition of protective requirements and glare device effectiveness. Transition risk-based model components for hazard evaluations of laser and broad-band optical systems. Mature generalized dose-response component models for future analysis of emerging laser technologies such as fiber and Diode Pumped Alkali Laser (DPAL) systems.			
FY 2020 Plans: Initiate validation and verification experiments for 3-dimensional tissue models of laser exposures. Complete studies of alternate laser wavelength bioeffects for use in high-energy lasers and the assessment of relative hazards. Transition model for probabilistic evaluation of risks from laser exposures on Air Force and DoD laser ranges. Advance dose-response models to include severe retinal and skin optical radiation exposures. Develop metrics for the influence of optical distortion in evaluating developing eye protection technology. Mature models for combining separate images of same retinal or skin area into one image with higher fidelity of injury.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.889 million. Justification for the increase is described in the plans above.			
Title: Radio Frequency Bioeffects	8.952	10.873	11.809

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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 627757 / <i>Bioeffects</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Description: Conduct laboratory experiments and field research to enable safe exploitation of directed energy technologies for communication, target identification, and weapons development.</p> <p>FY 2019 Plans: Focus on molecular signatures of Radio Frequency (RF) overexposure to assess acute and chronic bioeffects of RF overexposures in operational situations. Complete scalability matrix for fast thermal gradients exposures for transition from contact to free field application. Continued advancements in fast thermal gradient research. Investigating damage effects of high average power exposures.</p> <p>FY 2020 Plans: Conduct in vivo measurement of high average power exposures and high peak power microwave exposures to identify and baseline novel bioeffects. Build thermo-acoustic dosimetry techniques for in vivo assessment of high power sources including RF acoustics. Determine acute and chronic bioeffects from emerging sources such as particle beam. Expand in vivo molecular signature of RF exposure to assess acute and chronic bioeffects of RF to inform exposure scenarios.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.936 million. Justification for the increase is described in the plans above.</p>				
<p>Title: Molecular Bioeffects</p> <p>Description: Protect airman from toxic chemicals and materials and enhance performance capability under demanding training and mission activities through molecular bioscience research. Investigate the underlying molecular-biological mechanisms contributing to airman physical and cognitive performance optimization.</p> <p>FY 2019 Plans: Complete toxicological analysis of several relevant aerospace fluids, such as hydraulics, coolants, lubricants and jet fuels that may negatively affect high performance aircraft operators. Begin development of an Air Force Specific In Vitro Screen (AFSIVS) to enable rapid and accurate assessment of potentially toxic chemicals and materials including nanoparticles. Conduct studies to develop safe and effective fatigue counter measures to improve Airmen performance in physically or mentally intensive operational environments. Complete initial characterization and toxicity evaluation of particle aerosol in post-detonated areas to define exposure limits for the warfighter. Conduct developmental studies to create an organ on chip technology that enables rapid and accurate assessment of potentially toxic aerospace materials, with special emphasis on advanced acquisition materials that includes nanoparticles.</p> <p>FY 2020 Plans:</p>		9.783	8.703	0.000

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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602202F / <i>Human Effectiveness Applied Research</i>	Project (Number/Name) 627757 / <i>Bioeffects</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Starting in FY 2020, this work will be performed under Project 625328, Human Dynamics Evaluation, Molecular Bioeffects effort.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$8.703 million. Funding decreased due to the Molecular Bioeffects effort being transferred to Project 625328, Human Dynamics Evaluation.			
Accomplishments/Planned Programs Subtotals	29.130	33.823	27.125

C. Other Program Funding Summary (\$ in Millions)
N/A

Remarks

D. Acquisition Strategy
N/A

E. Performance Metrics
Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	192.846	218.419	198.775	0.000	198.775	196.753	201.123	208.608	213.049	Continuing	Continuing
623012: <i>Advanced Propulsion Technology</i>	-	27.912	26.813	29.802	0.000	29.802	26.465	28.557	29.599	30.212	Continuing	Continuing
623048: <i>Combustion and Mechanical Systems</i>	-	10.733	10.691	11.134	0.000	11.134	11.345	11.578	11.998	12.245	Continuing	Continuing
623066: <i>Turbine Engine Technology</i>	-	53.304	52.429	56.582	0.000	56.582	57.940	59.137	61.290	62.558	Continuing	Continuing
623145: <i>Aerospace Power Technology</i>	-	38.736	51.602	37.213	0.000	37.213	35.540	35.023	36.435	37.296	Continuing	Continuing
624847: <i>Rocket Propulsion Technology</i>	-	57.594	72.340	59.302	0.000	59.302	60.628	61.891	64.167	65.511	Continuing	Continuing
625330: <i>Aerospace Fuel Technology</i>	-	4.567	4.544	4.742	0.000	4.742	4.835	4.937	5.119	5.227	Continuing	Continuing

A. Mission Description and Budget Item Justification

This effort develops propulsion and power technologies to achieve enabling and revolutionary aerospace technology capabilities. The effort has six projects, each focusing on a technology area critical to the Air Force. The Advanced Propulsion Technology project develops high-speed air breathing propulsion engines to include combined cycle, ramjet, and hypersonic scramjet technologies to enable revolutionary propulsion capability for the Air Force. The Combustion and Mechanical Systems project develops engine mechanical system technologies: bearings, seals, drives, and lubricants as well as combustion components, concepts, and technologies for legacy and advanced turbine engines. The Turbine Engine Technology project develops enabling capabilities to enhance performance and affordability of existing weapon systems and develops component technologies for ultra high pressure ratio, substantially improved durability, and adaptive cycle engine architecture to provide optimized performance, fuel efficiency, and life for widely varying mission needs. The Aerospace Power Technology project develops electrical power and thermal control technologies for military applications that remove operational limitations and enable advanced vehicle designs and high-power mission systems. The Rocket Propulsion Technology project develops advances in rocket propulsion technologies for space access, space maneuver, missiles, the sustainment of strategic systems, and tactical rockets. The Aerospace Fuel Technology project evaluates hydrocarbon-based fuels for legacy and advanced turbine engines, scramjets, pulse detonation, and combined-cycle engines. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>
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As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	192.695	190.919	214.984	0.000	214.984
Current President's Budget	192.846	218.419	198.775	0.000	198.775
Total Adjustments	0.151	27.500	-16.209	0.000	-16.209
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	5.000	27.500			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-4.849	0.000			
• Other Adjustments	0.000	0.000	-16.209	0.000	-16.209

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 623145: Aerospace Power Technology

Congressional Add: *Program increase*

Congressional Add: *Program increase - thermal management technologies*

Congressional Add: *Program increase - next generation heat exchangers*

Congressional Add Subtotals for Project: 623145

Project: 624847: Rocket Propulsion Technology

Congressional Add: *Program increase - centers of excellence*

Congressional Add: *Program increase - next generation hall thrusters*

Congressional Add Subtotals for Project: 624847

	FY 2018	FY 2019
	4.877	0.000
	0.000	6.000
	0.000	6.500
Congressional Add Subtotals for Project: 623145	4.877	12.500
	0.000	5.000
	0.000	10.000
Congressional Add Subtotals for Project: 624847	0.000	15.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>
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Congressional Add Details (\$ in Millions, and Includes General Reductions)

	FY 2018	FY 2019
Congressional Add Totals for all Projects	4.877	27.500

Change Summary Explanation

Decrease in FY 2020 of \$16.209 million is due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602203F / Aerospace Propulsion				Project (Number/Name) 623012 / Advanced Propulsion Technology			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
623012: <i>Advanced Propulsion Technology</i>	-	27.912	26.813	29.802	0.000	29.802	26.465	28.557	29.599	30.212	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops combined/advanced cycle air breathing high-speed (up to Mach 5) and hypersonic (Mach 5 to 7) propulsion technologies to provide revolutionary propulsion options for the Air Force. These new engine technologies will enable future high-speed/hypersonic weapons and aircraft concepts. The primary focus is on hydrocarbon-fueled engines capable of operating over a broad range of flight Mach numbers. Efforts include modeling, simulations, and proof of concept demonstrations of critical components; advanced component development; and ground-based demonstrations.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Hypersonic Scramjet Technologies	27.912	26.813	29.802
Description: Develop robust hydrocarbon fueled scramjet engine components and technologies to improve performance, operability, durability, and scalability for future platforms.			
FY 2019 Plans: Continue to develop and demonstrate advanced engine components to improve scramjet operating margin and to refine scramjet scaling laws for reusable applications: continue to develop techniques to decrease scramjet take-over from Mach 4.5 to Mach 3.5 to provide robust options for Combined Cycle Engines (CCE). Continue to develop low internal drag flame stabilization devices and flight test engine components.			
FY 2020 Plans: Continue to develop and demonstrate advanced engine components to improve scramjet operating margin and to refine scramjet scaling laws for reusable applications. Continue to develop low internal drag flame stabilization devices and flight test engine components. Initiate propulsion studies and design efforts required for the development and demonstration of an engine flight test in FY2022 that expands the flight environment of current high speed propulsion systems.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$2.989 million. Funding increased due to additional propulsion technology design and development activities, leading to a proposed flight test in FY 2022 that expands the military utility of advanced scramjets.			
Accomplishments/Planned Programs Subtotals	27.912	26.813	29.802

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623012 / <i>Advanced Propulsion Technology</i>

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>				Project (Number/Name) 623048 / <i>Combustion and Mechanical Systems</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
623048: <i>Combustion and Mechanical Systems</i>	-	10.733	10.691	11.134	0.000	11.134	11.345	11.578	11.998	12.245	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project evaluates lubricants, mechanical systems, and combustion concepts for advanced turbine engines, pulse detonation engines, and combined cycle engines. This project also develops technologies to increase turbine engine operational reliability, durability, mission flexibility, maintainability, and performance while reducing weight, fuel consumption, and cost of ownership. Applications include: missiles, aircraft, and re-usable high-speed vehicles. Analytical and experimental areas of emphasis include: lubricants, bearings, mechanical systems diagnostics, mechanical systems prognostics, rotor dynamics, oil-less engine technology, optical diagnostics, fundamental combustion, detonations, combustors, and afterburners. Lubricants for these engines must be thermally stable, cost-effective, and operate over a broad range of conditions. Advanced combustion concepts must be cost-effective, durable, and reduce pollutant emissions. A portion of this project supports adaptive cycle technologies. Adaptive cycle technologies develops component technology for an adaptive cycle engine architecture that provides both optimized performance and fuel efficiency for widely varying mission needs.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Combustion Technologies	4.469	4.451	4.600
Description: Develop, test, and evaluate revolutionary combustion and propulsion concepts for gas turbine, pulse detonation, and combined cycle engines for missiles, manned and unmanned systems.			
FY 2019 Plans: Continue to explore interactions and effects of compressor and turbine components on the combustor and combustor materials to reduce engine weight and increase efficiency. Continue using advanced diagnostics to obtain high-quality datasets that can be made available to and used by academia and industry for model development and verification. Continue the determination of necessary reference performance and operability combustion systems and metrics to decrease the cost of certifying new and alternative fuels in weapon systems. Continue to support development of advanced computational fluid dynamics models to reduce combustor and augmentor design costs. Continue development of computations, modeling and simulation, and research experimentation of advanced combustion concepts including pressure gain combustion components and system level architectures. Continue to explore advanced combustion and flameholding concepts working towards improved understanding at relevant operating conditions such as sub-atmospheric (less than 1 atmosphere) and high pressure (greater than 10 atmospheres).			
FY 2020 Plans: Continue to explore interactions and effects of compressor and turbine components on the combustor and combustor materials to reduce engine weight and increase efficiency. Continue using advanced diagnostics to obtain high-quality datasets that can			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623048 / <i>Combustion and Mechanical Systems</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>be made available to and used by academia and industry for model development and verification. Continue the determination of necessary reference performance and operability combustion systems and metrics to decrease the cost of certifying new and alternative fuels in weapon systems. Continue to support development of advanced computational fluid dynamics (CFD) models to reduce combustor and augmentor design costs. Continue development of computations, modeling and simulation, and research experimentation of advanced combustion concepts including pressure gain combustion components and system level architectures. Continue to explore advanced combustion and flameholding concepts working towards improved understanding at relevant operating conditions such as sub-atmospheric (less than 1 atmosphere) and high pressure (greater than 10 atmospheres); this includes initiating fundamental combustion modeling and fluid-dynamic phenomena on high speed systems and rocket propulsion and advanced turbine engine applications, identifying modeling and simulation concepts/approaches to address combustion chemistry and physics and light/matter interactions, for high speed systems exploring turbulent combustion modeling in advanced configurations, exploring advanced combustion including pressure gain propulsion as it relates to new applications and architectures.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.149 million. Justification for the increase is described in the plans above.</p>			
<p>Title: Diagnostic Technologies</p> <p>Description: Develop and demonstrate optical, electromechanical, and laser diagnostic tools and sensors for application to revolutionary propulsion technologies.</p> <p>FY 2019 Plans: Continue development and demonstration of diagnostic systems for high-bandwidth kHz-MHz measurements of combustion chemistry and physics. Continue to seek to increase time scales of interest, size of regions explored, and increasing the number of species and their concentrations. Continue the development of diagnostic techniques to include 1) time-division-multiplexed hyperspectral absorption spectroscopy, 2) pulse-burst lasers, and 3) ultrashort-pulse (picosecond, femtosecond) lasers. Continue application of the insights gained to engine test cells and fielded systems. Continue to provide sufficient data to support CFD combustion model development, including development and application of fast laser systems and various atomic tracers for high-speed, planar visualization of mixing as applied in gas-turbine and hypersonic/scramjet propulsion systems. Continue development of diagnostic tools/methods for robust measurement capability in engine test cells and full annular ground test environments. Continue development of portable measurement capability for engine testing.</p> <p>FY 2020 Plans: Continue development and demonstration of diagnostic systems for high-bandwidth kilohertz to megahertz (kHz-MHz) measurements of combustion chemistry and physics: expand the diagnostic-technologies portfolio beyond current efforts to detonation devices and pressure-gain combustion (e.g., rotating-detonation engines), hypersonic/scramjet propulsion, and</p>	0.710	0.708	0.790

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623048 / <i>Combustion and Mechanical Systems</i>

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
munitions; increase focus on high-pressure combustion, such as that associated with rocket systems, including propulsion at near-critical and supercritical conditions. Continue the development of diagnostic techniques to include 1) time-division-multiplexed hyperspectral absorption spectroscopy, 2) pulse-burst lasers, and 3) ultrashort-pulse (picosecond, femtosecond) lasers. Continue application of the insights gained to engine test cells and fielded systems including development and deployment of fiber-coupled sensor systems based on hyperspectral absorption spectroscopy. Continue to provide sufficient data to support computational fluid dynamics (CFD) combustion model development, including development and application of fast laser systems and various atomic tracers for high-speed, planar visualization of mixing as applied in gas-turbine and hypersonic/scramjet propulsion systems. Continue development of diagnostic tools/methods for robust measurement capability in engine test cells and full annular ground test environments. Continue development of portable measurement capability for engine testing. Initiate advanced algorithms for tomographic reconstruction and spatiotemporal nonlinear data analysis to assess the rich data sets generated in the fundamental experiments and system testing described above.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.082 million. The justification for the increase is described in the plans above.			

Title: Lubricant Technologies	2.741	2.731	2.734
Description: Develop, test, and qualify advanced turbine engine lubricants. Generate and maintain military specifications for aviation engine lubricants.			
FY 2019 Plans: Continue developing innovative fluids (i.e., ionic fluids/additives) as potential high temperature lubricants for high-Mach and future high performance engines. Demonstrate Enhanced Ester (EE) oils in rig testing and design studies of turbine engines. Continue transitioning EE oil to F-35 and F-22 fleet. Continue developing on-line mechanical system health monitoring technologies. Continue the implementation of new lubricant traction models into updated bearing design codes. Continue supporting the warfighter on field-related mechanical system issues.			
FY 2020 Plans: Continue developing innovative fluids (i.e., ionic fluids/additives) as potential high temperature lubricants for high-Mach and future high performance engines. Complete demonstration of Enhanced Ester (EE) oils in rig testing and design studies of turbine engines. Complete transitioning EE oil to F-35 and F-22 fleet. Continue identification and development on in-line mechanical system health monitoring sensor technology. Continue the implementation of new lubricant traction models into updated bearing design codes. Refine bearing design codes to include advanced traction, rheological, and heat generation models: develop advanced algorithms for mechanical system health monitoring and condition based maintenance, apply high-temperature lubricant			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623048 / <i>Combustion and Mechanical Systems</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
technologies to magneto and electro-rheological fluids for smart dampers and engine vibration control. Continue supporting the warfighter on field-related mechanical system issues. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.003 million. Justification for the increase is described in the plans above.				
Title: Bearing Technologies Description: Develop and test advanced bearing material technology and bearing concepts for small, intermediate, and large-scale turbine engine applications. FY 2019 Plans: Continue developing physics-based bearing life model based on bearing alloy fatigue & microstructural investigations, including bearing life factors for advanced bearing materials. Continue work on small magnetic bearings & oil-free bearings for small & medium scale Unmanned Aircraft System (UAS), hi-Mach cruise missile and low-cost engines. Continue the integration of new bearing modeling simulation tools into full-engine design models. Continue development of active thrust-balance/prognostic health management (PHM) system for large man-rated and medium-scale propulsion. FY 2020 Plans: Continue developing physics-based bearing life model based on bearing alloy fatigue & microstructural investigations, including bearing life factors for advanced bearing materials. Include fatigue life, fault evolution, and parametric heat generation of advanced material systems into the models. Continue development of oil-free bearing technologies for small & medium scale UAS, expendable and low-cost engines. Continue the integration of new bearing modeling simulation tools into full-engine design models. Continue development of active thrust-balance/PHM system for large man-rated and medium-scale propulsion: demonstrate algorithms for active bearing thrust modulation for optimum performance and life in large turbine engines, demonstrate smart damper capabilities for control of turbine engine vibration, initiate investigation into the potential of additive manufacturing to develop robust, high-performance bearing compartment seals. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.209 million. Justification for the increase is described in the plans above.		2.813	2.801	3.010
Accomplishments/Planned Programs Subtotals		10.733	10.691	11.134
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623048 / <i>Combustion and Mechanical Systems</i>

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>				Project (Number/Name) 623066 / <i>Turbine Engine Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
623066: <i>Turbine Engine Technology</i>	-	53.304	52.429	56.582	0.000	56.582	57.940	59.137	61.290	62.558	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops technology to increase turbine engine operational reliability, durability, mission flexibility, and performance, while reducing weight, fuel consumption, and cost of ownership. Analytical and experimental areas of emphasis are fans and compressors, high temperature combustors, turbines, internal flow systems, controls, augmentor and exhaust systems, integrated power and thermal management systems, engine inlet integration, mechanical systems, adaptive cycle technologies, and structural design. This project develops component technology for an adaptive cycle engine architecture that provides both optimized performance and fuel efficiency for widely varying mission needs. This project supports joint Department of Defense, agency, and industry efforts to focus turbine propulsion technology on national needs. The project plan is relevant across capability areas for global responsive strike, tactical and global mobility, responsive space lift, and persistent intelligence, surveillance, and reconnaissance (ISR).

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Turbofan/Turbojet Engine Core Technologies	23.874	23.482	23.772
Description: Develop core turbofan/turbojet engine components (i.e., compressors, combustors, and turbines) for fighters, bombers, sustained supersonic/hypersonic cruise vehicles, and transports.			
FY 2019 Plans: Continue development and validation of modeling and simulation tools for the design and analysis of advanced turbine components with improved durability for adaptive cycle engines. Continue development of improved compressor aerodynamic design tools and analysis methods to extend engine operability and efficiency.			
FY 2020 Plans: Continue development and validation of modeling and simulation tools for the design and analysis of advanced turbine components with improved durability for adaptive cycle engines: develop and validate new architectures, critical technologies and new designs of adaptive core technologies; formulate a plan for detailed design, fabrication, and testing of component technology rigs for adaptive cores; conduct key technology rig tests to validate or determine new modeling cycles and designs; explore new approaches for variable core technologies, including use of high-temperature materials, integrated propulsion, power and thermal technologies and responsive controls. Continue development of improved compressor aerodynamic design tools and analysis methods to extend engine operability and efficiency.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.290 million. Justification for the increase is described in the plans above.			
Title: Turbofan/Turbojet Engine Fan, Low Pressure Turbine, and Integration Technologies	23.941	23.550	23.936

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623066 / <i>Turbine Engine Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Description: Develop turbofan/turbojet engine components (i.e., fans, nozzles, etc.) used in engines for fighters, bombers, sustained supersonic strike and hypersonic cruise vehicles, and transports.</p> <p>FY 2019 Plans: Continue development of modeling and simulation tools, including methods to predict behavior of serpentine inlets and nozzles. Develop and validate modeling and simulation tools for the design and analysis of advanced low pressure turbine components to enable lower cost/weight systems with improved aero-performance for increased range and endurance at altitude. Continue to identify control technology elements applicable to integrated propulsion/power/thermal solutions. Initiate and complete defining actionable indicators and assess interface control gaps to enable decision-based informed life cycle tools.</p> <p>FY 2020 Plans: Continue development of modeling and simulation tools, including methods to predict behavior of serpentine inlets and nozzles. Continue to develop and validate modeling and simulation tools for the design and analysis of advanced low pressure turbine components to enable lower cost/weight systems with improved aero-performance for increased range and endurance at altitude. Continue to identify control technology elements applicable to integrated propulsion/power/thermal solutions. Initiate integration of power and thermal modeling of advanced architectures into aircraft system level multidisciplinary analysis and optimization tools: explore new control methods for integrated propulsion, power and thermal management, initiate evaluation of integration of advanced augmentors and ramburners, initiate exploration of new expendable and attritable architectures.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.386 million. Justification for the increase is described in the plans above.</p>				
<p>Title: Missile and Remotely Piloted Aircraft Engine Technologies</p> <p>Description: Develop limited life engine components for missile and remotely piloted aircraft (RPA) applications, including long-range supersonic and hypersonic vehicles.</p> <p>FY 2019 Plans: Continue to demonstrate advanced component designs in rig testing. Continue to utilize validation data to develop improved test protocol for small engine augmentor designs. Continue development and validation of modeling and simulation tools for the design and analysis of turbine components with mission-tailored aero-performance and highly efficient cooling geometries. Continue to develop and validate parameter, process, and performance modeling for components manufactured through additive technologies. Continue to develop and validate rules and tools to enable flexible design for targeted life applications.</p> <p>FY 2020 Plans: Continue to demonstrate advanced component designs in rig testing. Continue to utilize validation data to develop improved test protocol for small engine augmentor designs. Continue development and validation of modeling and simulation tools for</p>		4.491	4.417	5.529

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623066 / <i>Turbine Engine Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>the design and analysis of turbine components with mission-tailored aero-performance and highly efficient cooling geometries. Continue to develop and validate parameter, process, and performance modeling for components manufactured through additive technologies. Continue to develop and validate rules and tools to enable flexible design for targeted life applications. Initiate exploration of new innovative architectures and critical technologies for small missile and remotely piloted aircraft applications; evaluate critical technologies that will increase range, performance, durability, electrical power and thermal capacity on these systems. Initiate exploration of new small engine technologies that can operate in high speed applications. Initiate rig testing to validate targeted life models.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.112 million. Funding increased due to additional emphasis on small missile and unmanned aerial vehicle engines.</p>			
<p>Title: Turboshaft/Turboprop and Small Turbofan Engine Technologies</p> <p>Description: Develop components for turboshaft/turboprop and small turbofan engines for trainers, rotorcraft, special operations aircraft, and theater transports.</p> <p>FY 2019 Plans: Continue development and validation of modeling and simulation tools to achieve very high levels of loading for advanced low pressure turbine components. Continue the exploration of advanced integrated engine controls with potential for synergistic airframe system level benefits.</p> <p>FY 2020 Plans: Continue development and validation of modeling and simulation tools to achieve very high levels of loading for advanced low pressure turbine components. Continue the exploration of advanced integrated engine controls with potential for synergistic airframe system level benefits. Initiate exploration of new small and medium size engine technologies for increased fuel efficiency, propulsive capability, power and thermal management, and reduced life cycle cost. Initiate identification of new architectures and critical technologies for integrated power and thermal systems. Initiate identification of requirements and develop models for simulation of highly integrated systems.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$2.365 million. Funding increased due to additional emphasis in reliable and cost effective small engines with extended range.</p>	0.998	0.980	3.345
Accomplishments/Planned Programs Subtotals	53.304	52.429	56.582

C. Other Program Funding Summary (\$ in Millions) N/A

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623066 / <i>Turbine Engine Technology</i>
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C. Other Program Funding Summary (\$ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>				Project (Number/Name) 623145 / <i>Aerospace Power Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
623145: <i>Aerospace Power Technology</i>	-	38.736	51.602	37.213	0.000	37.213	35.540	35.023	36.435	37.296	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops integrated electrical and thermal management components, controls and systems for military aerospace applications. Power component technologies are developed to increase reliability, maintainability, commonality, affordability, and supportability of aircraft and flight line equipment. Research is conducted in energy storage and hybrid power system technologies to enable special purpose applications. Electrical power and thermal management technologies enable future military megawatt level power and thermal management needs. Controls and system integration technologies ensure the interoperability of aircraft, power, thermal, engine and other systems and subsystems. This project supports development of electrical power and thermal management components, controls and systems suitable for applications to legacy and future aircraft platforms including strike and mobility concepts. Lightweight power systems suitable for other aerospace applications are also developed.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: High Power System Technologies	33.859	39.102	37.213
Description: Develop integrated system architecture, controls, and component technologies to provide for the large amounts of electrical power needed, and concurrent thermal mitigation required, by current and future manned and unmanned systems.			
FY 2019 Plans: Continue development of system and component electrical power, electro-mechanical, and thermal technologies for high-power applications. Continue development of hybrid approaches to power generation, storage, and application as well as thermal management. Continue testing of subsystems hardware in conjunction with continued platform level tip-to-tail modeling and simulation energy optimization. Continue development of advanced, safe energy storage, power distribution, and management systems to include Silicon Carbide applications and batteries. Continue power and thermal development toward demonstration of tactical aircraft high-power payload capability, e.g. laser weapon system. Continue analysis and development of adaptive power and thermal control systems for high-power aircraft. Continue the development of advanced power options for small unmanned aircraft. Initiate weapon system contractor support for platform integration of advanced power and thermal system architectures.			
FY 2020 Plans: Continue development of system and component electrical power, electro-mechanical, and thermal technologies for high-power applications. Continue development of hybrid approaches to power generation, storage, and application as well as thermal management. Continue testing of subsystems hardware in conjunction with continued platform level tip-to-tail modeling and simulation energy optimization. Continue development of advanced, safe energy storage, power distribution, and management systems to include Silicon Carbide applications and batteries. Continue power and thermal development toward demonstration of tactical aircraft high-power payload capability, e.g. laser weapon system. Continue analysis and development of adaptive			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 623145 / <i>Aerospace Power Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
power and thermal control systems for high-power aircraft. Complete the development of advanced power options for small unmanned aircraft. Continue weapon system contractor support for platform integration of advanced power and thermal system architectures.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$1.889 million. Funding decreased due to realignment and consolidation of Air Force Science and Technology Applied Research funding for future Air Force capabilities.			
Accomplishments/Planned Programs Subtotals	33.859	39.102	37.213

	FY 2018	FY 2019
<i>Congressional Add:</i> Program increase	4.877	0.000
<i>FY 2018 Accomplishments:</i> Conducted Congressionally directed efforts		
<i>FY 2019 Plans:</i> Not Applicable		
<i>Congressional Add:</i> Program increase - thermal management technologies	0.000	6.000
<i>FY 2018 Accomplishments:</i> Not Applicable		
<i>FY 2019 Plans:</i> Conduct Congressionally directed efforts		
<i>Congressional Add:</i> Program increase - next generation heat exchangers	0.000	6.500
<i>FY 2018 Accomplishments:</i> Not Applicable		
<i>FY 2019 Plans:</i> Conduct Congressionally directed efforts		
Congressional Adds Subtotals	4.877	12.500

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>				Project (Number/Name) 624847 / <i>Rocket Propulsion Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624847: <i>Rocket Propulsion Technology</i>	-	57.594	72.340	59.302	0.000	59.302	60.628	61.891	64.167	65.511	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops rocket propulsion technologies for space access, space maneuver, the sustainment of strategic systems (including solid boost/missile propulsion, post boost control, aging and surveillance efforts), and tactical missiles. Analytical and experimental areas of emphasis are propellants, propellant management, combustion, rocket material applications, technology for sustainment of strategic systems, and innovative space propulsion concepts. Technologies of interest will improve reliability, performance, survivability, affordability, and environmental compatibility of these systems. Develop technologies to reduce the weight and cost of components using new materials and improved designs and manufacturing techniques. All efforts in this project contribute to the sustainment of the rocket propulsion industry, providing rocket propulsion technology for the entire Department of Defense (DoD). Technologies under this project enable capabilities of interest to both DoD and National Aeronautics and Space Administration (NASA). Tasks include: modeling and simulation; proof of concept tests of critical components; advanced component development; and ground-based tests. Aging and surveillance tasks could reduce lifetime prediction uncertainties for individual motors by 50%, enabling motor replacement for cause. All thrusts are part of the Rocket Propulsion 21 (RP21) collaboration and are reviewed by a DoD level steering committee yearly for relevance to DoD missions and progress towards RP21 Goals.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Fuel Technologies	7.014	10.791	10.081
Description: Develop, characterize, and test advanced hydrocarbons, energetics, solid propellants, and monopropellants to increase space launch payload capability and refine new synthesis methods.			
FY 2019 Plans: Continue developing solid rocket propellant binder systems for intended use across a variety operationally relevant conditions. Continue to conceive, synthesize, scale-up, and characterize novel energetic ingredients, including both fuels and oxidizers, for use across the span of space and missile applications from strategic and tactical boost through in-space thrust and attitude control. Continue transferring knowledge for making green mono-propellants to the United States industrial base. Continue to formulate, scale-up, and evaluate formulations of solid and liquid rocket propellants. Continue to identify, evaluate, and adapt 21st century material processing equipment to enable more rapid and agile development and more precise products. Continue support for National Aeronautics and Space Administration's (NASA) Green Propellant Infusion mission to demonstrate a non-toxic ionic liquid based propulsion system in space. Continue research in high-temperature resins, insulators, and composite case fabrication techniques to enable high mass-fraction rocket motor cases. Continue high-performance bi-propellant synthesis and formulation.			
FY 2020 Plans: Continue developing solid rocket propellant binder systems for intended use across a variety operationally relevant conditions. Continue to conceive, synthesize, scale-up, and characterize novel energetic ingredients, including both fuels and oxidizers,			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 624847 / <i>Rocket Propulsion Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>for use across the span of space and missile applications from strategic and tactical boost through in-space thrust and attitude control. Continue transferring knowledge for making green mono-propellants to the United States industrial base. Continue to formulate, scale-up, and evaluate formulations of solid and liquid rocket propellants. Continue to identify, evaluate, and adapt 21st century material processing equipment to enable more rapid and agile development and more precise products. Complete support for NASAs Green Propellant Infusion mission to demonstrate a non-toxic ionic liquid based propulsion system in space. Continue research in high-temperature resins, insulators, and composite case fabrication techniques to enable high mass-fraction rocket motor cases. Continue high-performance bi-propellant synthesis and formulation.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.710 million. Justification for the decrease is described in the plans above.</p>			
<p>Title: Liquid Engine Combustion Technologies</p> <p>Description: Develop advanced liquid engine combustion technology for improved performance, while preserving chamber lifetime and reliability needs for engine uses in heavy lift space vehicles.</p> <p>FY 2019 Plans: Continue evaluation of methane multi-injector designs in hot-fire conditions. Continue hot fire tests in combustion stability rig. Continue combustion stability modeling critical future hydrocarbon fueled liquid rocket engines. Continue the delivery combustion stability codes with nearly-complete set of validation data to rocket community, enabling more robust and stable engine designs. Continue developing understanding of hydrocarbon fuel production, expanding testing in to methane fuels and other cryogenic cooling. Continue the employment of new fuel and material operating limitations, manufacturing processes, and launch goals in cycle analysis to identify trade space for future engines. Continue to evaluate and develop advanced material solutions for high temperature components in rocket engines. Continue installation of new test facility that will fill the current capability gap and allow for fast, low-cost testing of multi-injector designs and stability strategies at conditions relevant to the demands of both Department of Defense and industry for next-generation engines (including use of liquid oxygen and higher pressures and thrust).</p> <p>FY 2020 Plans: Continue evaluation of methane multi-injector designs in hot-fire conditions. Continue hot fire tests in combustion stability rig. Continue combustion stability modeling critical for future hydrocarbon fueled liquid rocket engines. Continue the delivery of combustion stability codes with nearly-complete set of validation data to rocket community, enabling more robust and stable engine designs. Continue developing understanding of hydrocarbon fuel production, expanding testing into methane fuels and other cryogenic cooling. Continue the employment of new fuel and material operating limitations, manufacturing processes, and launch goals in cycle analysis to identify trade space for future engines. Continue to evaluate and develop advanced material solutions for high temperature components in rocket engines. Continue installation of new test facility that will fill the current capability gap and allow for fast, low-cost testing of multi-injector designs and stability strategies at conditions relevant to the</p>	6.997	8.601	8.262

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 624847 / <i>Rocket Propulsion Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
demands of both Department of Defense and industry for next-generation engines (including use of liquid oxygen and higher pressures and thrust). Initiate development of rotating detonation rocket engine technologies.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.339 million. Justification for the decrease is described in the plans above.				
Title: Advanced Liquid Engine Technologies		18.325	12.615	11.212
Description: Develop advanced liquid engine technologies for improved performance, while increasing life and reliability needs for engine uses in expendable and reusable launch vehicles.				
FY 2019 Plans: Development of enabling Hydrocarbon Boost (HCB) technology for future spacelift concepts and risk reduction activities for the development of HCB technologies were completed in FY 2018. Continue exploring engine concepts for next generation, beyond 2035, launch vehicles and concepts to effect cost reductions. Initiate sub-scale risk mitigation and technology maturation activities to incorporate into next generation engine concepts.				
FY 2020 Plans: Complete exploring engine concepts for next generation, beyond 2035, launch vehicles and concepts to effect cost reductions. Continue sub-scale risk mitigation and technology maturation activities to incorporate into next generation engine concepts. Initiate modular component integration and interaction research activities supporting next generation engine concepts.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$1.403 million. Funding decreased due to completion of next generation engine concept exploration.				
Title: On-Orbit Propulsion Technologies		13.498	13.865	16.013
Description: Develop solar electric, solar thermal, chemical, and advanced propulsion technologies for station-keeping, repositioning, and orbit transfer for satellites and satellite constellations.				
FY 2019 Plans: Continue scale-up research of advanced chemical propellants with particular focus on transition of numerical tools and experimental methodologies for advanced mono-propellants to spacecraft industry. Continue to support the maturation of advanced plume diagnostics for both chemical and electric propulsion thrusters with potential for integrated state-of-health application. Continue to expand the validation and verification programs (both experimental and flight) to quantify accuracy of modeling and simulation tools developed to support thruster-spacecraft integration. Continue transition and support of thruster/				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 624847 / <i>Rocket Propulsion Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
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<p>plume modeling framework to spacecraft industry, with addition of advanced electric propulsion (EP) thruster models, to industry partners. Continue to explore advanced EP and chemical thruster concepts and assess new spacecraft propulsion requirements.</p> <p>FY 2020 Plans: Continue scale-up research of advanced chemical propellants with particular focus on transition of numerical tools and experimental methodologies for advanced mono-propellants to spacecraft industry. Continue to support the maturation of advanced plume diagnostics for both chemical and electric propulsion thrusters with potential for integrated state-of-health application. Continue to expand the validation and verification programs (both experimental and flight) to quantify accuracy of modeling and simulation tools developed to support thruster-spacecraft integration. Continue transition and support of thruster/plume modeling framework to spacecraft industry, with addition of advanced EP thruster models, to industry partners. Continue to explore advanced electric propulsion and chemical thruster concepts and assess new spacecraft propulsion requirements</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$2.148 million. Funding increased due to additional development of advanced electric thrusters.</p>			
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<p>Title: Space Access and Strike Applications</p> <p>Description: Develop missile propulsion and boost technologies for space access and strike applications.</p> <p>FY 2019 Plans: Continue to develop advanced tactical propulsion. Continue development and evaluation of next generation of updated, physics-based modeling, simulation, and analysis tools for missile propulsion components and applications. Continue to develop advanced component technologies for missile propulsion applications for strategic and strike systems helping to ensure their long-term sustainment. Continue development of technology options for post-boost systems exploring cost reductions, performance improvements, and potential for commonality among Air Force, Navy, and Missile Defense Agency. Continue propellant development efforts including long-life propellants.</p> <p>FY 2020 Plans: Continue to develop advanced tactical propulsion. Complete development of technology options for post-boost systems exploring cost reductions, performance improvements, and potential for commonality among Air Force, Navy, and Missile Defense Agency. Continue propellant development efforts including long-life propellants. Continue development and evaluation of next generation of updated, physics-based modeling, simulation, and analysis tools for missile propulsion components and applications. Continue to develop advanced component technologies for missile propulsion applications for strategic and strike systems helping to ensure their long-term sustainment.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	7.313	6.307	5.431
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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 624847 / <i>Rocket Propulsion Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 decreased compared to FY 2019 by \$0.876 million. Justification for the decrease is described in the plans above.			
Title: Ballistic Missile Technologies	4.447	5.161	8.303
Description: Develop missile propulsion technologies and aging and surveillance technologies for ballistic missiles.			
FY 2019 Plans: Continue to apply to user needs and unique problems next generation chemical and aging mechanism modeling, simulation, and analysis tools and sensor system designs/tools. Continue development of advanced sensor, non-destructive evaluation, modeling and supporting technology development efforts to detect and explain phenomena further improve data acquisition and reduce uncertainty in ballistic and tactical missile solid rocket motor life predictions. Continue long-term validation of tools through long-term aging of sub-scale motors. Continue to monitor and periodically test sub-scale motors to validate the sensor and analytical analysis of each motor.			
FY 2020 Plans: Continue to apply next generation of chemical and aging mechanism modeling, simulation, and analysis tools, sensor schemes and tools, to user needs and unique problems. Continue development of advanced sensor, non-destructive evaluation, modeling and supporting technology development efforts to detect and explain phenomena further improve data acquisition and reduce uncertainty in ballistic and tactical missile solid rocket motor life predictions. Continue long-term validation of tools through long-term aging of sub-scale motors. Continue to monitor and periodically test sub-scale motors to validate the sensor and analytical analysis of each motor.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$3.142 million. Funding increased due to a larger quantity of simultaneous efforts supporting tool and sensor development.			
Accomplishments/Planned Programs Subtotals	57.594	57.340	59.302

	FY 2018	FY 2019
Congressional Add: Program increase - centers of excellence	0.000	5.000
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts		
Congressional Add: Program increase - next generation hall thrusters	0.000	10.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 624847 / <i>Rocket Propulsion Technology</i>
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	FY 2018	FY 2019
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts		
Congressional Adds Subtotals	0.000	15.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>				Project (Number/Name) 625330 / <i>Aerospace Fuel Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625330: <i>Aerospace Fuel Technology</i>	-	4.567	4.544	4.742	0.000	4.742	4.835	4.937	5.119	5.227	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project evaluates hydrocarbon-based fuels for legacy and advanced turbine engines, scramjets, pulse detonation and combined cycle engines. This project also considers fuel related concepts that can increase turbine engine operational reliability, durability, mission flexibility, energy efficiency, and performance while reducing weight, fuel consumption, and cost of ownership. Applications include missiles, aircraft, sustained high-speed vehicles, and responsive space launch. Analytical and experimental areas of emphasis include evaluations of fuel properties and characteristics of alternative fuels developed from unconventional sources (such as coal, natural gas, biomass, and combinations thereof), unique/alternate fuels and components used in integrated thermal and energy management systems including high heat sink fuel capability, fuels logistics and associated vulnerabilities, and combustion diagnostics and engine emissions measurements.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Alternative Fuels</p> <p>Description: Conduct evaluations and perform technical assessments of alternative hydrocarbon fuels derived from coal, natural gas, and biomass for use in legacy and advanced aerospace systems.</p> <p>FY 2019 Plans: Continue evaluation of fully-synthetic jet fuels produced from alcohol and triglyceride feedstocks.</p> <p>FY 2020 Plans: Continue evaluation of fully-synthetic jet fuels produced from alcohol, triglyceride and other feedstocks including: conducting full characterization of fuel composition and relate these to potential performance impacts. Continue leveraging ongoing collaborative efforts in fuels characterization with Navy, Army, Federal Aviation Administration, and National Aeronautics and Space Administration to leverage and complement on-going research.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.007 million. The justification for the decrease is described in the plans above.</p>	0.101	0.100	0.093
<p>Title: Integrated Thermal and Energy Management</p> <p>Description: Develop and demonstrate advanced components and conduct performance assessments of advanced aircraft integrated thermal and energy management systems for engines and aircraft.</p> <p>FY 2019 Plans: Continue the evaluation of advanced additives, catalysts, and fuel composition approaches to minimize endothermic fuel coking.</p> <p>FY 2020 Plans:</p>	1.422	1.415	1.496

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 625330 / <i>Aerospace Fuel Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
Continue the evaluation of advanced additives, catalysts, and fuel composition approaches to minimize endothermic fuel coking for Hypersonic applications. Initiate work in model development and simulation tools for Integrated Thermal and Energy Management assessment of efficient technologies and architectures. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.081 million. The justification for the increase is described in the plans above.				
Title: Fuel Logistics Description: Study and evaluate low-cost approaches to reduce fuel logistics footprint to reduce cost. Study fuel logistics vulnerabilities and develop detection and mitigation technologies. FY 2019 Plans: Continue the development of fuel temperature limits for full-life fuel systems as part of integrated power and thermal management systems. FY 2020 Plans: Continue the development of fuel temperature limits for full-life fuel systems as part of integrated power and thermal management systems: identify sensing approaches to be able to capture fuel stability limiters to minimize logistics vulnerabilities, work on bio detection and mitigation to support logistics readiness, coordinate and collaborate with Army and Navy in identification and development of sensing technologies. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.081 million. Justification for the increase is described in the plans above.		1.422	1.415	1.496
Title: Combustion Emissions and Performance Description: Develop and test advanced emissions diagnostic techniques for airbreathing propulsion systems. Conduct evaluations of the combustion and emissions characteristics of aviation fuels. FY 2019 Plans: Complete the development of Aerospace Recommended Practice (ARP) for particulate emissions measurements for engine certification, joint with Federal Aviation Administration (FAA), NASA, and industry. FY 2020 Plans: Initiate aviation fuels combustion tests to identify fuel composition performance impacts. Initiate Lean Blow test, cold start testing and emissions tests and analysis to work on model developments to be able to establish composition to performance correlations. FY 2019 to FY 2020 Increase/Decrease Statement:		1.622	1.614	1.657

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602203F / <i>Aerospace Propulsion</i>	Project (Number/Name) 625330 / <i>Aerospace Fuel Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$0.043 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	4.567	4.544	4.742

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	157.078	171.307	202.912	0.000	202.912	209.631	211.243	200.426	205.529	Continuing	Continuing
622002: <i>Electronic Component Technology</i>	-	41.902	43.633	43.667	0.000	43.667	46.948	48.328	50.983	52.048	Continuing	Continuing
622003: <i>EO Sensors & Countermeasures Tech</i>	-	24.473	28.820	30.934	0.000	30.934	31.497	32.147	33.290	33.989	Continuing	Continuing
622005: <i>Cyber Technology</i>	-	6.428	6.196	9.387	0.000	9.387	9.480	8.324	9.253	9.995	Continuing	Continuing
624920: <i>Electronic Warfare Technology</i>	-	0.000	0.000	34.795	0.000	34.795	37.176	34.580	34.900	35.582	Continuing	Continuing
626095: <i>Sensor Fusion Technology</i>	-	31.370	32.281	32.063	0.000	32.063	32.685	34.498	35.578	36.819	Continuing	Continuing
627622: <i>RF Sensors and Countermeasures Tech</i>	-	52.905	60.377	52.066	0.000	52.066	51.845	53.366	36.422	37.096	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops the technology base for Air Force aerospace sensors and electronic combat. Advances in aerospace sensors are required to increase combat effectiveness by providing anytime, anywhere surveillance, reconnaissance, precision targeting, and electronic warfare (EW) capabilities. To achieve this progress, this program pursues simultaneous advances in: 1) generating, controlling, receiving, and processing electronic and photonic signals for radio frequency (RF) sensor aerospace applications; 2) electro-optical (EO) and infrared (IR) aerospace sensor technologies for a variety of offensive and defensive uses; 3) radio frequency antennas and associated electronics for airborne and space surveillance, together with active and passive electro-optical/infrared sensors; 4) technologies to manage and fuse on-board sensor information for timely, comprehensive situational awareness; 5) technology for affordable, trusted, and reliable, all-weather surveillance, reconnaissance, and precision strike radio frequency sensors and electronic combat systems; and 6) technologies that aid in the discovery and mitigation of cyber vulnerabilities in avionics systems. This program has been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

Project 624920, Electronic Warfare, is new for FY 2020. Starting FY 2020, some Electronic Warfare activities will be transferred from PE 0602204F, Aerospace Sensors, Project 627622, RF Sensors and Countermeasures Tech, and PE 0603270F, Electronic Combat Technology, Project 633720, EW Quick Reaction Capabilities, and

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>
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Project 63691X, EO/IR Warning & Countermeasures Tech, in order to rebalance the mix of Applied Research and Advanced Technology Development. This is an administrative realignment only and not a new start.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	152.782	166.534	174.632	0.000	174.632
Current President's Budget	157.078	171.307	202.912	0.000	202.912
Total Adjustments	4.296	4.773	28.280	0.000	28.280
• Congressional General Reductions	-0.142	-0.227			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	6.500	5.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-0.023	0.000			
• SBIR/STTR Transfer	-2.039	0.000			
• Other Adjustments	0.000	0.000	28.280	0.000	28.280

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 622002: *Electronic Component Technology*

Congressional Add: *Program Increase*

Congressional Add Subtotals for Project: 622002

Project: 627622: *RF Sensors and Countermeasures Tech*

Congressional Add: *Program increase - research by minority leaders program*

Congressional Add: *Program increase - Air Force Minority Leaders Program*

Congressional Add Subtotals for Project: 627622

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	3.949	0.000
	3.949	0.000
	2.468	0.000
	0.000	5.000
	2.468	5.000
	6.417	5.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	
<u>Change Summary Explanation</u> Increase in FY 2020 due to civilian pay repricing adjustment; realignment of electronic warfare science and technology (S&T) funding from PE 0603270F, Electronic Combat Technology, to PE 0602204F, Aerospace Sensors; and the realignment and consolidation of Air Force Applied Research S&T funding for Future Air Force Capabilities Applied Research efforts.		

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>				Project (Number/Name) 622002 / <i>Electronic Component Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622002: <i>Electronic Component Technology</i>	-	41.902	43.633	43.667	0.000	43.667	46.948	48.328	50.983	52.048	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project focuses on electronics and optoelectronics technologies that generate, control, receive, and process electromagnetic spectrum for aerospace sensor and electronic warfare (EW) applications. The enabling technologies developed under this project will be used for intelligence, surveillance, reconnaissance, electronic warfare, battlespace access, and precision engagement capabilities. The technologies developed include exploratory electronic and optoelectronic devices, components, microsystems and subsystems.

This project also assesses designs, develops, fabricates, and demonstrates the associated technologies for integrating combinations of these component technologies. The project aims to demonstrate significantly smaller size, lower weight, lower cost, lower power dissipation, higher reliability, trustworthiness and improved performance. The device and subsystem technology developments under this project are military unique; they are based on Air Force and other Department of Defense weapon systems requirements in the areas of radar, communications, electronic warfare, positioning, navigation, timing, and smart weapons.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Sensor Subsystems	6.891	10.033	8.425	0.000	8.425
Description: Develop, analyze, demonstrate, and perform engineering trade studies for technologies for compact, affordable, multi-function subsystems for aerospace sensors.					
FY 2019 Plans: Complete demonstration of models and simulations for low-cost, multi-function radio frequency subsystems. Complete digital beamforming demonstration. Continue the development of subsystem prototypes for attritable platforms. Initiate demonstration of low-cost on-board sensor processing subsystem.					
FY 2020 Base Plans: Complete wideband multifunction array technology development. Continue development of direction finding subsystem prototypes for attritable systems. Continue research for highly miniaturized and power-efficient on-board sensor processing. Initiate low cost electro-optical/infrared sensor subsystem development.					
FY 2020 OCO Plans: Not applicable					
FY 2019 to FY 2020 Increase/Decrease Statement:					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 622002 / <i>Electronic Component Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 decreased compared to FY 2019 by \$1.608 million. Funding decreased due to completion of joint effort with the Defense Advanced Research Projects Agency developing a wideband, multifunction radio frequency array.					
<p>Title: Electronic Devices</p> <p>Description: Assess, research, develop, demonstrate and transition revolutionary and evolutionary electronic devices and their associate technologies.</p> <p>FY 2019 Plans: Continue to refine tools and methods to design, build, and analyze game changing component technologies. Continue evaluation of emerging component technologies against device concept baseline for multi-use applications and continue development of prototypes from identified emerging device concepts. Continue wide-bandgap device technology development for power generation and management. Complete demonstration of models for high-performance, high-frequency, millimeter-wave device technologies for power amplification. Continue commercialization of Air Force foundry process to industry. Initiate high-voltage L and S-Band power amplifier demonstration.</p> <p>FY 2020 Base Plans: Complete commercialization of Air Force foundry process to industry. Complete millimeter-wave gallium nitride transistor development. Continue wide-bandgap device technology development for power generation and management. Initiate advanced wide band-gap model development for multi-use applications. Initiate novel wide-band gap switch integration with millimeter-wave transistor development.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.271 million. Justification for this decrease is described in plans.</p>	7.914	7.738	7.467	0.000	7.467
<p>Title: Electro-Optical/Infrared (EO/IR) Components</p> <p>Description: Research, develop, demonstrate and transition electro-optical/infrared (EO/IR) components for next generation intelligence, surveillance, reconnaissance (ISR) and countermeasures.</p> <p>FY 2019 Plans: Continue to explore and evaluate innovative materials and devices for tunability, increased bandwidth and multi-wavelength operation. Continue compact, tunable, laser source prototype. Complete demonstration of first</p>	9.950	9.271	8.725	0.000	8.725

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 622002 / <i>Electronic Component Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>generation reconfigurable focal plane array. Continue to develop a semiconductor optomechanical oscillator. Initiate demonstration of high pulse power midwave infrared laser source.</p> <p>FY 2020 Base Plans: Complete neutron/radiation detector demonstration. Complete wavelength conversion demonstration. Complete preliminary narrow line width laser demonstration. Continue to explore and evaluate innovative materials and devices for tunability, increased bandwidth and multi-wavelength operation. Continue compact, tunable, laser source prototype. Initiate advanced avalanche photo-diode based focal plane array development.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.546 million. Justification for this decrease is described in plans.</p> <p>Title: Trusted Electronics for Intelligence, Surveillance, Reconnaissance and Avionics Systems</p> <p>Description: Investigate and develop designs of trusted electronic and optoelectronic systems when integrating commercially available solutions commercial-off-the-shelf with emerging government-off-the-shelf advanced technologies. Areas of development include: multi-function radio frequency and electro-optical subsystems, advanced electronic and optoelectronic materials, on-board sensor processing, high-frequency power modules, electro-optical/infrared sources, electro-optical/infrared detectors, beam control and waveguides, and trusted and reliable electronics.</p> <p>FY 2019 Plans: Complete initial demonstration of trust in design and trust in fabrication. Complete baseline modeling and simulation architecture development to inform and predict mission assurance for highly integrated microsystems, devices and materials. Continue development of prototype trustworthiness assessment capability. Initiate reliability assessments of advanced heterogeneously integrated microsystems.</p> <p>FY 2020 Base Plans: Continue investigations and demonstration of trust in design and trust in fabrication. Advance modeling and simulation capability to improve predictive capability of mission assurance for highly integrated microsystems, devices, and materials. Continue development of prototype trustworthiness assessment capability. Continue reliability assessments of advanced heterogeneously integrated microsystems. Investigate application of trust into sensors and sensor systems to deter reverse engineering and exploitation of critical hardware and</p>	7.557	9.797	12.157	0.000	12.157

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / Aerospace Sensors	Project (Number/Name) 622002 / Electronic Component Technology
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
software technology and impede unwanted technology transfer, alteration of system capability, and prevent the development of countermeasures to our systems. FY 2020 OCO Plans: Not applicable FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$2.360 million. Funding increased due to realignment from multiple efforts within Project 627622, RF Sensors and Countermeasures Tech.					
Title: Advanced Highly Integrated Microsystems for Intelligence, Surveillance, Reconnaissance and Electronic Warfare Description: Develop, mature, and demonstrate critical electronic technologies to enable revolutionary electronic warfare subsystems. FY 2019 Plans: Complete demonstration of highly-reconfigurable microsystem prototype. Complete baseline demonstration of militarily relevant integrated photonic circuit prototype. Continue assessment of microsystem fabrication techniques to militarily-relevant electronics and optoelectronics. Initiate development and demonstration of integrated wideband and adaptable transceiver microsystem. FY 2020 Base Plans: Complete initial demonstration of integrated wideband and adaptable transceiver microsystem. Initiate development of photonically enabled electronic intelligence subsystem. Initiate development of photonic antenna remoting concept. Initiate development of integrated and adaptable transceiver microsystems. Continue development of military relevant heterogeneous integration technologies. Continue development of additive techniques for advanced electronic subsystems. FY 2020 OCO Plans: Not applicable FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.099 million. Justification for this increase is described in plans.	5.641	6.794	6.893	0.000	6.893
Accomplishments/Planned Programs Subtotals	37.953	43.633	43.667	0.000	43.667
	FY 2018	FY 2019			
Congressional Add: Program Increase	3.949	0.000			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 622002 / <i>Electronic Component Technology</i>
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	FY 2018	FY 2019
<i>FY 2018 Accomplishments:</i> Conducted congressionally directed effort.		
<i>FY 2019 Plans:</i> Not applicable		
Congressional Adds Subtotals	3.949	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>				Project (Number/Name) 622003 / <i>EO Sensors & Countermeasures Tech</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622003: <i>EO Sensors & Countermeasures Tech</i>	-	24.473	28.820	30.934	0.000	30.934	31.497	32.147	33.290	33.989	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project determines the technical feasibility of advanced electro-optical aerospace sensor technologies for a variety of offensive and defensive uses. The sensor technologies under development range from the ultraviolet through the infrared portion of the spectrum. Related efforts include improvements in avionics integration, digital processing, analysis tools, and sensor architectures. One of the project's main goals is to improve electro-optical and related technologies for the detection, tracking, and identification of non-cooperative and difficult targets, such as those obscured by camouflage or acquired at great range. This project also develops the passive and active imaging sensors and algorithms needed to enable precision targeting in severe weather. These technologies are critical to future aerospace surveillance and targeting. Other project goals include advanced electro-optical threat warning and countermeasures.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Passive Electro-Optical/Infrared Sensing in Contested Environments	8.157	13.674	15.126	0.000	15.126
Description: Develop innovative passive optical sensing technology to support surveillance and reconnaissance in contested environments. Develop high performance focal planes, aperture technologies, sensing architectures, and imaging techniques capable of long range target detection and characterization for intelligence, surveillance, reconnaissance and air-to-air sensing.					
FY 2019 Plans: Develop an enhanced midwave infrared imaging upgrade to a fielded reconnaissance sensor. Show performance improvements using appropriate sensor and component technology models. Fabricate and test in a laboratory environment, an electro-optical sensor fore-optic based on novel concepts in optical engineering. Develop and implement the necessary optical metrology capability to support laboratory testing of the novel optics. Continue development of novel computational techniques for image restoration and noise reduction. Demonstrate the most promising candidates in a virtual environment. Complete and test in a laboratory environment, a pathfinder for small size, weight and power hyperspectral imaging for a small unmanned aircraft system. Generate appropriate sensor models to adequately explore performance in a virtual environment. Explore and develop signal processing and data processing algorithms needed to enhance the capabilities of the novel sensor hardware. Refine passive sensing computer models to support infrared search and track technology trade analyses. Generate models for new sensor architectures and examine potential new capabilities resulting from a systems engineering strategy on cross domain electro-optical sensing for Air Force					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 622003 / <i>EO Sensors & Countermeasures Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>relevant missions using broad capability computer simulations, including engagement level and campaign level simulations.</p> <p>FY 2020 Base Plans: Continue infrared search and track simulation and modeling to support detection and tracking algorithm development and sensor performance assessment. Complete design and development of focal plane array and the associated read-out integrated circuit. Continue evaluation of compact hyperspectral imaging sensor performance through low altitude flight testing on a surrogate platform. Conduct a flight test of a breadboard active hyperspectral imaging system on a lab-class aircraft. Evaluate a novel atmospheric characterization technique through continued data collections coincident with truth sensors. Perform studies to leverage dual-band sensor concepts for improved turbulence mitigation to improve the useful range beyond the current state of the art. Initiate studies into improving standoff high-resolution imaging by leveraging new machine learning algorithms.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.452 million. Funding increased due to increased emphasis in passive electro-optical/infrared sensing technologies including indications and warnings and targeting support against airborne threats.</p>					
<p>Title: Laser Radar Sensing in Contested Environments</p> <p>Description: Develop innovative laser sensing technology for non-cooperative identification of airborne and ground-based targets in contested environments. Develop optical spectrum transmitters, detectors and agile aperture technologies capable of sensing multiple target characteristics for robust non-cooperative target identification and future infrared countermeasure systems.</p> <p>FY 2019 Plans: Test, in a laboratory environment, a distributed aperture laser radar system for imaging at long ranges, beyond the diffraction limit of the available individual apertures. Assess the architecture's limitations and its potential for implementation on current Air Force sensor pods and aircraft internal integration. Demonstrate the use of a holographic laser radar sensor for wavefront sensing and examine its potential for applications where wavefront sensing is a limitation. Continue development of a reduced size, weight and power laser amplifier suitable for laser radar applications such as synthetic aperture ladar and unmanned aircraft systems based active sensing.</p>	16.316	15.146	15.808	0.000	15.808

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 622003 / <i>EO Sensors & Countermeasures Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Enhance efforts to develop an end-to-end laser system computer model. Integrate the software with other system-level models. Continue component development for low cost, low size, weight and power laser radar suited for implementation on an unmanned aircraft system. Analyze potential system improvements brought about by enhanced components through computer modeling and laboratory test. Continue tests of prototype remote laser vibrometry and range-Doppler sensing technology to aid in target identification. Examine utility of candidate automated signal recognition software. Continue investigation of advanced system architectures and evaluate candidates.</p> <p><i>FY 2020 Base Plans:</i> Flight test near real time image formation algorithms for new 3-dimension sensing mode using focal planes built the previous year. Continue development of image formation algorithms for synthetic aperture lidar with advanced waveforms. Continue development of advanced focal planes for coherent lidar sensing; including completing design and build of integrated dewar cooler assembly. Develop approach for real-time determination of volumetric turbulence using a holographic sensor. 3-dimension shape sensing efforts will focus on real-time delivery of processed products with an emphasis on overcoming high sensor data rates. Enhance existing aided target recognition algorithms with a focus on segmenting target from its background. Continue to enhance state of the art lidar simulations to support requirements definition, engagement modeling, enhanced processing development, and synthetic data generation for aided target recognition efforts. Investigate use of photon counting arrays for coherent sensing. Investigate the use of polarization gratings as a low cost / low size weight and power method of steering lidar system.</p> <p><i>FY 2020 OCO Plans:</i> Not applicable</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.662 million. Justification for this increase is described in the plans above.</p>					
Accomplishments/Planned Programs Subtotals	24.473	28.820	30.934	0.000	30.934

C. Other Program Funding Summary (\$ in Millions) N/A
Remarks

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / Aerospace Sensors	Project (Number/Name) 622003 / EO Sensors & Countermeasures Tech

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>				Project (Number/Name) 622005 / <i>Cyber Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622005: <i>Cyber Technology</i>	-	6.428	6.196	9.387	0.000	9.387	9.480	8.324	9.253	9.995	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project focuses on technologies for cyber security and resilience of Air Force weapon systems. First, this project improves our understanding of avionics cyber vulnerabilities by investigating the fundamental nature of avionics vulnerabilities including: how they come about, how they can be discovered, how they can be quantified and categorized, how they can be exploited, and how they can be removed or mitigated to secure the system. Second, this project aims to develop adaptable and resilient hardware/software for real-time avionics cyber-attack pattern recognition and develop a protection system with the capability for autonomous learning, adaptation, and self-protection. Lastly, this project investigates open architecture concepts and technologies to deliver capability flexibility to Air Force avionics and weapon systems. These technologies are matured via integrated capability demonstrations.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Vulnerability Mitigation	2.806	2.704	4.096	0.000	4.096
Description: Apply knowledge from computer vulnerability discovery and computer security to investigate capabilities for identifying and mitigating vulnerabilities in United States avionics systems resulting from software and/or hardware deficiencies. Develop automated and cost effective processes, techniques and technologies to assist in the identification of potential vulnerabilities.					
FY 2019 Plans: Continue to investigate means to automate and make scalable vulnerability assessment tools and techniques. Continue to investigate systematic methodologies to achieve repeatable and reliable cyber test to expand our understanding of root causes of avionics vulnerabilities. Investigate and apply our insights to evaluate feasibility of new capability concepts on next generation avionics architectures designed from a secure foundation. Begin transition from hands-on legacy platform assessment and tool development to developing guidelines, methodologies, and technologies for cyber hardening and resilience.					
FY 2020 Base Plans: Continue development of automated tools for performing cyber test and assessment of weapon systems. As more mature capabilities are transitioned, assess community capability gaps and develop/enhance tools as needed. Continue research and development of vulnerability mitigation technologies for legacy platforms and to support the maturation of next generation avionics architectures. Baseline technologies and capabilities will be available this year and will need continued investigation into their secure use. Increase focus on cyber test/assessment/situational-awareness of next-generation architectures. Investigate cyber assessment					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 622005 / <i>Cyber Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
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methodologies and open system architecture standards and approaches to reduce susceptibility of legacy and next-generation avionics architectures.

FY 2020 OCO Plans:
Not applicable

FY 2019 to FY 2020 Increase/Decrease Statement:
FY 2020 increased compared to FY 2019 by \$1.392 million. Funding increased due to realignment from PE 0603270F, Electronic Combat Technology, Project 634335, Cyber Concepts, Avionics Cyber Vulnerabilities effort.

Title: Adaptive Cyber Protections	3.622	3.492	5.291	0.000	5.291
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Description: Develop avionics protection tools and capabilities to enable manned and unmanned aircraft, avionics, and related support equipment to automatically adapt to and withstand cyber attacks. Research and develop tools, methodologies and architecture guidelines that enable the design of avionics systems with sense, learn and adapt capabilities.

FY 2019 Plans:
Continue investigations into platform-independent malware feature selection capability. Investigate automation and optimization of malware detection and classification work using machine learning techniques. Investigate adaptable cyber protections and technologies to achieve cyber resilience in avionics systems.

FY 2020 Base Plans:
Mature malware detection, diagnostics, and attack inferencing capabilities for avionics and mission systems. Research and develop real-time response mechanisms for cyber-attacks. Perform research and development in software, firmware and hardware diversity to enable resilient cyber defense systems. Research and develop real-time instruction-level malware detection capabilities to enable early warning and response to cyber threats. Develop automated test generation tools to expose malware embedded within mission critical software and firmware. Investigate evolutionary/co-evolutionary algorithms as a means to develop test samples for the above detection algorithms and to investigate adaptive countermeasures to malware and cyber-attacks. Research and develop cyber resilient immune systems for avionics and mission systems. Investigate cyber protection methodologies and open system architecture standards and approaches to improve cyber resiliency of legacy and next-generation avionics architectures.

FY 2020 OCO Plans:

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 622005 / <i>Cyber Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Not applicable					
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$1.799 million. Funding increased due to realignment from PE 0603270F, Electronic Combat Technology, Project 634335, Cyber Concepts, Avionics Cyber Protections effort.					
Accomplishments/Planned Programs Subtotals	6.428	6.196	9.387	0.000	9.387

C. Other Program Funding Summary (\$ in Millions)
N/A

Remarks

D. Acquisition Strategy
N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>				Project (Number/Name) 624920 / <i>Electronic Warfare Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624920: <i>Electronic Warfare Technology</i>	-	0.000	0.000	34.795	0.000	34.795	37.176	34.580	34.900	35.582	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and assesses affordable, reliable all weather radio frequency countermeasure concepts for aerospace applications covering the range of radio frequency sensors including communications, navigation, intelligence, surveillance and reconnaissance (ISR), and radar, both active and passive, across the air, land, sea, space and cyber domains. It develops and evaluates technology for electronic warfare, integrated radar and electronic warfare systems, and electro-optical/infrared seeker defeat. This project develops the radio frequency warning and countermeasure technology for advanced electronic warfare and information operations applications. The project also explores technologies to maintain a military advantage in positioning, navigation and timing integrity, accuracy, and resiliency as well as on aircraft mission assurance - the protection of airborne platforms, manned and unmanned, in contested environments. The ultimate goal of the project is to ensure unrestricted access to the airspace and the electromagnetic spectrum in contested and congested environments.

Project 624920, Electronic Warfare, is new for FY 2020. In FY 2019 and prior, this work is reported under PE 0602204F, Aerospace Sensors, Project 627622, RF Sensors and Countermeasures Tech, and PE 0603270F, Electronic Combat Technology, Project 633720, EW Quick Reaction Capabilities, and Project 63691X, EO/IR Warning & Countermeasures Tech. This is administrative realignment only and not a new start.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Positioning, Navigation and Timing in Contested/Denied Environments	0.000	0.000	9.663	0.000	9.663
Description: Develop resilient position, navigation and timing sensors. Explore position, navigation and timing solutions to enable novel distributed radio frequency sensing and countermeasure techniques. Develop technology base to provide solutions addressing navigation and timing threats.					
FY 2019 Plans: For FY 2019 and prior, this work is performed under Project 627622, RF Sensors and Countermeasures Tech, Hybrid Sensor Technologies effort and under PE 0603270F, Electronic Combat Technology, Project 633720, EW Quick Reaction Capabilities, Position, Navigation and Timing for Contested/Denied Environments effort.					
FY 2020 Base Plans: Expand research on navigation sensor integration, modeling, and simulation to incorporate open architecture attributes. Continue alternative navigation, bandwidth efficient communications for navigation, and timing technologies research. Continue exploring technologies to support precise time and time transfer with airborne platforms to enable coherent sensing (intelligence, surveillance, reconnaissance) and effects (electronic					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 624920 / <i>Electronic Warfare Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
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warfare). Start development of trust techniques to enable military use of global navigation satellite systems. Continue modeling and simulation studies to address the multispectrum threat to satellite navigation systems.

FY 2020 OCO Plans:

Not applicable

FY 2019 to FY 2020 Increase/Decrease Statement:

FY 2020 increased compared to FY 2019 by \$9.663 million. Funding increased due to the realignment from Project 627622, RF Sensors and Countermeasures Tech, Hybrid Sensor Technologies effort, and PE 0603270F, Electronic Combat Technology, Project 633720, EW Quick Reaction Capabilities, Position, Navigation and Timing for Contested/Denied Environments effort.

Title: Radio Frequency Electronic Warfare Technologies

Description: This project develops the radio frequency warning and countermeasure technology for advanced electronic warfare and information operations applications. Specifically, it develops techniques and technologies to detect and counter the communications links and sensors of threat integrated air defense systems and hostile command and control networks.

FY 2019 Plans:

For FY 2019 and prior, this work is performed under Project 627622, RF Sensors and Countermeasures Tech, Radio Frequency Countermeasures Technologies effort.

FY 2020 Base Plans:

Continue research to demonstrate electronic warfare technologies that can reason about threat capabilities and intentions and the electromagnetic environment to synthesize an optimized response in a time frame to support aircraft survivability against adaptive and agile threats. Continue to extend research to address dynamic planning for collaborative autonomous electronic warfare systems. Continue the demonstration of robust modeling, simulation, and assessment capability to study the efficiency versus effectiveness of electronic support and electronic attack capabilities, including distributed electronic warfare assets and cognitive/autonomous technologies, against complex threat emitters in integrated air defense systems and in complex electromagnetic spectrum background environments. Continue research into effective management of electronic warfare assets in operational environments focusing on a multi-ship strike package employment. Start incorporation of electro-optical and radio frequency integrated engagement model development to meet multispectrum threats.

FY 2020 OCO Plans:

	0.000	0.000	17.631	0.000	17.631

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / Aerospace Sensors	Project (Number/Name) 624920 / Electronic Warfare Technology
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Not applicable					
<p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$17.631 million. Funding increased due to realignment from Project 627622, RF Sensors and Countermeasures Tech, Radio Frequency Countermeasures Technologies effort.</p> <p><i>Title:</i> Electro-Optical/Infrared Threat Warning and Countermeasures Technologies</p> <p><i>Description:</i> Develop electro-optical/infrared sensor countermeasure technologies. Explore novel concepts to enable electro-optical/infrared threat seeker exploitation and surrogate modeling. Conduct fundamental research in countermeasures to defeat electro-optical/infrared threat seekers. Conduct fundamental research on integrated electro-optical/infrared threat warning systems.</p> <p><i>FY 2019 Plans:</i> For FY 2019 and prior, this work is performed under Project 627622, RF Sensors and Countermeasures Tech, Radio Frequency Countermeasures Technologies effort, and PE 0603270F, Electronic Combat Technology, Project 63691X, EO/IR Warning & Countermeasures Tech, Advanced Electro-Optical/Infrared Warning and Countermeasures effort.</p> <p><i>FY 2020 Base Plans:</i> Continue threat characterization and countermeasures development of new threats to include new jam codes and countermeasure techniques. Continue development of low-cost missile warning capabilities. Investigate long-range missile and laser warning technology concepts. Start incorporation of electro-optical and radio frequency integrated engagement model development to meet multispectrum threats.</p> <p><i>FY 2020 OCO Plans:</i> Not applicable</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$7.501 million. Funding increased due to realignment from Project 627622, RF Sensors and Countermeasures Tech, Radio Frequency Countermeasures Technologies effort, and PE 0603270F, Electronic Combat Technology, Project 63691X, EO/IR Warning & Countermeasures Tech, Advanced Electro-Optical/Infrared Warning and Countermeasures effort.</p>	0.000	0.000	7.501	0.000	7.501
Accomplishments/Planned Programs Subtotals	0.000	0.000	34.795	0.000	34.795

C. Other Program Funding Summary (\$ in Millions)
N/A

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / Aerospace Sensors	Project (Number/Name) 624920 / Electronic Warfare Technology

C. Other Program Funding Summary (\$ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602204F / Aerospace Sensors				Project (Number/Name) 626095 / Sensor Fusion Technology			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
626095: <i>Sensor Fusion Technology</i>	-	31.370	32.281	32.063	0.000	32.063	32.685	34.498	35.578	36.819	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops foundational technologies required for closed-loop autonomous sensing employing multiple information domains, diverse sensor phenomena, and multiple platform types to provide intelligence, surveillance, and reconnaissance; target recognition; situational awareness and battlespace visualization; fire control; and battle damage assessment capabilities against a wide variety of targets engaged in multitudes of behaviors in a broad range of operational environments. This project conducts exploratory investigations to determine technology feasibility and estimate operational capability constraints associated with missions in future contested and highly contested operating environments, using cooperative and non-cooperative sensing sources. This project develops techniques to automate multi-sensor exploitation and information processing that leverage the data fusion, adaptive signal processing, and artificial intelligence / machine learning research communities. This project develops concepts and algorithms for efficient parallel processing, distributed processing, and high-performance computing in sensor data processing and synthetic data generation.

In FY 2020, efforts within this project are realigned to better reflect technical areas being emphasized such as autonomy, multi-domain and multi-sensor information processing, leverage of machine learning developments and enterprise-level modeling, simulation and analysis.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Target Signature Modeling	4.370	4.496	0.000	0.000	0.000
Description: Develop, evaluate, and demonstrate target signature models to support sensor exploitation algorithm development and testing for reconnaissance and strike mission applications.					
FY 2019 Plans: Continue development and initiate experimentation for multi-sensor feature level fusion for stationary target identification. Demonstrate space-time alignment with measured multi-sensor target primitive data with in-house multi-sensor test bench.					
FY 2020 Base Plans: Starting in FY 2020, this work will be performed under the Multi-Domain Sensing Effect and Analysis effort within Project 626095, Sensor Fusion Technology.					
FY 2020 OCO Plans: Not applicable					
FY 2019 to FY 2020 Increase/Decrease Statement:					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / Aerospace Sensors	Project (Number/Name) 626095 / Sensor Fusion Technology
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 decreased compared to FY 2019 by \$4.496 million. Funding decreased due to realignment to Multi-Domain Sensing Effect and Analysis effort within Project 626095, Sensor Fusion Technology.					
<p>Title: Sensor Exploitation Technologies</p> <p>Description: Develop technical methods required for algorithm performance models, performance driven sensing, layered sensing and other sensing and exploitation technologies impacted by automated exploitation capabilities.</p> <p>FY 2019 Plans: Develop optimized high performance computing-based deep learning synthetic aperture radar and electro-optical/infrared algorithm training process. Continue development of a closed-loop sensor mode controller for adaptive transmit and receive. Initiate development of methodology for feature level fusion within a single modality.</p> <p>FY 2020 Base Plans: Starting in FY 2020, this work will be performed under the Multi-Domain Sensing Effect and Analysis and Synthesis for Understanding efforts within Project 626095, Sensor Fusion Technology.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$6.858 million. Funding decreased due to realignment to Multi-Domain Sensing Effect and Analysis and Synthesis for Understanding efforts within Project 626095, Sensor Fusion Technology.</p>	6.667	6.858	0.000	0.000	0.000
<p>Title: Sensor Management for Automatic Target Recognition</p> <p>Description: Develop multi-platform and multi-sensor control strategies to create advantages for survival, autonomous sensing, and autonomous exploitation in contested environments. Incorporate sensing platform kinematics and external operating conditions into analyses of effective multi-sensor control and multiple intelligence data fusion capabilities. Assess advantages of multi-sensor closed loop control techniques for platform survival, command and control, intelligence, surveillance and reconnaissance, and strike missions. Enhance existing automatic target recognition sensor management, and sensor fusion technologies by application of multi-sensor data and distributed data processing.</p> <p>FY 2019 Plans:</p>	15.912	16.367	0.000	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 626095 / <i>Sensor Fusion Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Conduct enhanced multi-domain intelligence, surveillance and reconnaissance processing, exploitation and dissemination analysis. Develop electronic warfare/cyber effects toolbox. Demonstrate in simulation reasoning and replanner selection using multiple replanners and architectures. Initiate development of adaptive representation algorithms for high level information sharing. Initiate development a general framework for joint inference and control with arbitrary sensors.</p> <p>FY 2020 Base Plans: Starting in FY 2020, this work will be performed under the Multisource Knowledge Representation and Management effort within Project 626095, Sensor Fusion Technology.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$16.367 million. Funding decreased due to realignment to Multisource Knowledge Representation and Management effort within Project 626095, Sensor Fusion Technology.</p>					
<p>Title: Distributed Sensing for Automatic Target Recognition</p> <p>Description: Develop techniques and metrics for adaptive, penetrating, distributed radio frequency exploitation in contested environments.</p> <p>FY 2019 Plans: Investigate transition opportunities for real-time processing of bistatic air-to-ground moving target indication algorithms. Investigate transition opportunities for algorithms for imaging and identifying moving targets using geometric invariance. Continue to develop alternative algorithms for non-template-based synthetic aperture radar automatic target recognition exploitation. Plan bistatic X-band data collection with a moving receiver to demonstrate algorithms to exploit bistatic synthetic aperture radar data with unknown parameters in non-cooperative environments.</p> <p>FY 2020 Base Plans: Starting in FY 2020, this work will be performed under the Synthesis for Understanding and the Multisource Knowledge Representation and Management efforts within Project 626095, Sensor Fusion Technology.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	4.421	4.560	0.000	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 626095 / <i>Sensor Fusion Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>FY 2020 decreased compared to FY 2019 by \$4.560 million. Funding decreased due to realignment to Synthesis for Understanding and Multisource Knowledge Representation and Management efforts within Project 626095, Sensor Fusion Technology.</p> <p>Title: Synthesis for Understanding</p> <p>Description: Continue to develop novel techniques for behavioral and physical knowledge generation from multiple sensors, intelligence sources, domains (Air, Space, Cyber) and sources to include algorithm development, assessment, and experiments across multiple distributed, homogeneous and heterogeneous sensors. This effort will focus on technology areas of data association, entity detect/track/identification, information fusion, training with limited data, and data/performance modeling. The application of machine learning techniques to address technical challenges in contested environments is a particular emphasis.</p> <p>FY 2019 Plans: For FY 2019 and prior, this work is performed under the Sensor Exploitation Technologies effort within Project 626095, Sensor Fusion Technology.</p> <p>FY 2020 Base Plans: Develop capabilities for space-time alignment of multiple hard (physics-based) and soft (human-based) information sources. Model information uncertainty for multiple information sources (hard and soft). Apply deep and machine learning techniques to the detection/tracking/identification of stationary and moving entities, and for pattern of life understanding. Develop decision/feature-level fusion capabilities for physics-based information from multiple sensors/intelligence sources. Investigate fusion of hard and soft information sources for military-relevant applications. Design and evaluate training techniques, for example, blended measured-synthetic training, for deep and machine learning classifiers given limited measured data.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY2019 by \$13.380 million. Funding increased due to realignment from Sensors Exploitation Technologies effort within Project 626095, Sensor Fusion Technology to better reflect technical areas being emphasized such as autonomy, multi-domain and multi-sensor information processing, leverage of machine learning developments and enterprise-level modeling, simulation and analysis.</p>	0.000	0.000	13.380	0.000	13.380
<p>Title: Multi-Domain Sensing Effects and Analysis</p>	0.000	0.000	6.535	0.000	6.535

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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 626095 / <i>Sensor Fusion Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
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Description: This thrust will focus on two primary areas: (1) Multi domain sensing and effects mission analysis and (2) performance understanding and assessments. It will develop methodologies and modeling, simulation, and analysis tools to enable multi domain analysis and technology development, informing other efforts and projects across the directorate. Investments in modeling, simulation and analysis will represent current and next generation sensing platforms to include air, space, and cyber as well as the fusion of information amongst these three domains.

FY 2019 Plans:
For FY 2019 and prior, this work is performed under the Target Signature Modeling and the Sensor Exploitation Technologies efforts within Project 626095, Sensor Fusion Technology.

FY 2020 Base Plans:
Key applied research investments will be made in the following: 1) leverage academic partnerships with respect to specific Air Force applications in modeling, simulation and analysis, 2) design and build next generation correct fidelity performance models, 3) develop one or more challenge problems to support Air Force technology investment understanding, 4) perform in-the-field data collections to verify and validate performance using measured sensor data.

FY 2020 OCO Plans:
Not applicable

FY 2019 to FY 2020 Increase/Decrease Statement:
FY 2020 increased compared to FY 2019 by \$6.535 million. Funding increased due to realignment from Target Signature Modeling and Sensor Exploitation Technology efforts within Project 626095, Sensor Fusion Technology to better reflect technical areas being emphasized such as autonomy, multi-domain and multi-sensor information processing, leverage of machine learning developments and enterprise-level modeling, simulation and analysis.

Title: Multisource Knowledge Representation and Management	0.000	0.000	12.148	0.000	12.148
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Description: Develop, evaluate, and demonstrate models for sensing and for adversary behavior that support anticipatory asset tasking, characterization of latencies and related uncertainties, and joint inference and control. Develop multisource sensing techniques providing environment characterization consistent with the needs of automated and autonomous systems.

FY 2019 Plans:

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 626095 / <i>Sensor Fusion Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>For FY 2019 and prior, this work is performed under the Sensor Management for Automatic Target Recognition effort within Project 626095, Sensor Fusion Technology.</p> <p><i>FY 2020 Base Plans:</i> Continue to develop mission performance metrics for distributed sensing capabilities in which families of suitable solutions exist. Improve representational and computational efficiency of graph-based information fusion methods. Develop foundational algorithms for sensing management incorporating environment analysis, target tracking and recognition, and operationally representative external factors.</p> <p><i>FY 2020 OCO Plans:</i> Not applicable</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$12.148 million. Funding increased due to realignment from Sensor Management for Automatic Target Recognition effort within Project 626095, Sensor Fusion Technology to better reflect technical areas being emphasized such as autonomy, multi-domain and multi-sensor information processing, leverage of machine learning developments and enterprise-level modeling, simulation and analysis.</p>					
Accomplishments/Planned Programs Subtotals	31.370	32.281	32.063	0.000	32.063

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>				Project (Number/Name) 627622 / <i>RF Sensors and Countermeasures Tech</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
627622: <i>RF Sensors and Countermeasures Tech</i>	-	52.905	60.377	52.066	0.000	52.066	51.845	53.366	36.422	37.096	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and assesses affordable, reliable all weather radio frequency sensing and countermeasure concepts for aerospace applications covering the range of radio frequency sensors including communications, navigation, intelligence, surveillance and reconnaissance (ISR), and radar, both active and passive, across the air, land, sea, space and cyber domains. This project also develops and evaluates technology for intelligence, surveillance and reconnaissance sensors, fire control radars, electronic warfare, integrated radar and electronic warfare systems, and offensive information operations systems. It emphasizes the detection and tracking of surface and airborne targets with radio frequency signatures that are difficult to detect due to reduced radar cross sections, concealment and camouflage measures, severe clutter, or heavy jamming. Techniques exploited include the use of multiple radio frequency phenomenologies, multi-dimensional adaptive processing, advanced waveforms and knowledge-aided processing techniques. This project also develops concepts to counter threats to our aerospace systems. It develops and evaluates technology for electronic warfare, integrated radar and electronic warfare systems, and electro-optical/infrared seeker defeat. This project develops the radio frequency warning and countermeasure technology for advanced electronic warfare and information operations applications. The project also explores technologies to maintain a military advantage in positioning, navigation and timing integrity, accuracy, and resiliency.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Hybrid Sensor Technologies	11.134	12.842	0.000	0.000	0.000
Description: Develop hybrid sensor solutions to be responsive to needs and detect difficult targets. Develop resilient position, navigation and timing sensors. Explore position, navigation and timing solutions to enable novel distributed radio frequency sensing and countermeasure techniques. Develop technology base to provide solutions addressing threats that exploit multiple sensor phenomenologies.					
FY 2019 Plans: Continue research to provide optimal frameworks for hybrid navigation sensor integration and modeling and simulation. Continue alternative navigation and timing technologies research. Continue exploring technologies to support precise time and time transfer with airborne platforms. Continue bandwidth efficient communication protocol research to support collaborative state estimation techniques to enable common model referencing for position, navigation and timing in Global Positioning System denied environments. Continue modeling and simulation studies to address the multispectrum threat. Continue passive radar illumination selection manager					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 627622 / <i>RF Sensors and Countermeasures Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>hardware and software development and assess the utility of correlated multi-mode (for example synthetic aperture radar, moving target indication and signals intelligence) operation.</p> <p>FY 2020 Base Plans: Starting in FY 2020, this work will be performed under Project 624920, Electronic Warfare Technology, Positioning, Navigation and Timing in Contested/Denied Environments effort.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$12.842 million. Funding decreased due to realignment to Project 624920, Electronic Warfare Technology, Positioning, Navigation and Timing in Contested/Denied Environments effort.</p>					
<p>Title: Radio Frequency Sensor Technologies</p> <p>Description: Conduct applied research and development for the advancement of passive and active radio frequency sensors; including phenomenology, modeling and simulation, algorithm development, and experimentation. Plan, execute, and maintain state-of-the-art radio frequency sensor research and development facilities. Conduct research on sensing, learning, and adapting to enable the countering of emerging adaptive, agile radio frequency threats.</p> <p>FY 2019 Plans: Integrate passive radar illumination selection manager hardware and software and conduct data collection on a finite number of radio frequency emitters (cooperative/non-cooperative) and assess the utility of correlated multi-mode (synthetic aperture radar/moving target indicator/signals intelligence) operation.</p> <p>FY 2020 Base Plans: Analyze passive radar illumination selection manager collected data from the ground-based static testing to establish an experimental technical baseline for a future airborne experiment.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	14.717	8.128	9.127	0.000	9.127

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 627622 / <i>RF Sensors and Countermeasures Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 increased compared to FY 2019 by \$0.999 million. Justification for this increase is described in plans above.					
<p>Title: Multi-Band/Multi-Beam Technologies</p> <p>Description: Develop multi-band and multi-beam forming technologies. Address technologies for antenna array operations in dynamic sensor networks.</p> <p>FY 2019 Plans: Validate through radio frequency range testing simultaneous multibeam, conformal antenna with integrated radar/communication and multi-spectral signal processing functions on representative low-cost, size, weight and power constrained platforms (for example, Miniature Air-Launched Decoy). Continue to employ adaptive, reconfigurable and tunable detection methods and techniques as effective optional countermeasures on sensing blue force platforms.</p> <p>FY 2020 Base Plans: Continue to employ adaptive, reconfigurable and tunable detection methods and techniques as effective optional countermeasures to developing multi-mission, unmanned sensing blue force platforms such as the Low Cost Attributable Aircraft Technology effort.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.390 million. Funding increased due to realignment of civilian pay from Project 626095, Sensor Fusion Technology.</p>	10.071	11.315	12.705	0.000	12.705
<p>Title: Sensor Resource Management</p> <p>Description: Develop technology to enable optimization of sensor resources in contested environments on own-ship and multi-ship in manned, unmanned and manned/unmanned teaming concepts.</p> <p>FY 2019 Plans: Assess fidelity of sensor resource manager Air Force Simulation models with leveraged flight test data (radar, electro-optical/infrared) collected under Defense Advanced Research Projects Agency's System of Systems Integration Technology and Experimentation Program. Complete single ship sensor resource management</p>	14.515	9.411	10.567	0.000	10.567

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 627622 / <i>RF Sensors and Countermeasures Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>effort resulting in radio frequency multi-function/multi-mode use cases for size, weight and power constrained platforms.</p> <p>FY 2020 Base Plans: Utilize delivered sensor resource management tools to integrate data collected from the Defense Advanced Research Projects Agency System of Systems Integration Technology and Experimentation gauntlets and begin engineering study for multi-ship/multi-spectral sensor resource manager.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.156 million. Funding increased due to realignment of civilian pay from Project 626095, Sensor Fusion Technology.</p>					
<p>Title: Radio Frequency Countermeasure Technologies</p> <p>Description: This project develops the radio frequency warning and countermeasure technology for advanced electronic warfare and information operations applications. Specifically, it develops techniques and technologies to detect and counter the communications links and sensors of threat integrated air defense systems and hostile command and control networks.</p> <p>FY 2019 Plans: Conduct research to demonstrate electronic warfare technologies that can reason about threat capabilities and intentions and the electromagnetic environment to synthesize an optimized response in a time frame to support aircraft survivability against adaptive and agile threats. Extend research to address dynamic planning for collaborative autonomous electronic warfare systems. Demonstrate robust modeling and simulation capability to study the efficiency versus effectiveness of distributed electronic warfare assets including electronic support and electronic attack capabilities. Continue research into effective management of electronic warfare assets in operational environments focusing on a multi-ship strike package employment.</p> <p>FY 2020 Base Plans: Starting in FY 2020, this work will be performed under Project 624920, Electronic Warfare Technology, Radio Frequency Electronic Warfare Technologies effort.</p> <p>FY 2020 OCO Plans:</p>	0.000	13.681	0.000	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 627622 / <i>RF Sensors and Countermeasures Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Not applicable					
<p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$13.681 million. Funding decreased due to realignment to Project 624920, Electronic Warfare Technology, Radio Frequency Electronic Warfare Technologies effort.</p>					
<p><i>Title:</i> Future AF Capabilities Applied Research</p> <p><i>Description:</i> Investigate, design, and develop science and technologies supporting future Air Force capabilities to provide compelling advantage to the warfighter. To the greatest extent practical, research efforts will utilize modeling and simulation and cross-discipline systems integration (For example: air and space vehicles, avionics, propulsion, materials, human performance, cybersecurity, command, control, communications, computer and intelligence, sensors, electronic warfare, and conventional/unconventional weapons).</p> <p>The National Defense Strategy and Air Force Science and Technology 2030 Strategy will inform investments over the future years defense planning (FYDP).</p> <p><i>FY 2019 Plans:</i> In FY 2019, this work is performed under multiple projects and efforts within the following Air Force Science and Technology Programs: 0602102F, Materials; 0602201F, Aerospace Vehicle Technologies; 0602202F, Human Effectiveness Applied Research; 0602203F, Aerospace Propulsion; 0602204F, Aerospace Sensors; 1206601F, Space Technology; 0602602F, Conventional Munitions; 0602605F, Directed Energy Technology; and 0602788F, Dominant Information Science and Methods.</p> <p><i>FY 2020 Base Plans:</i> Continue to investigate and mature science and technology that enables future warfighting concepts to provide leap-ahead capabilities. The National Defense Strategy and Air Force Science and Technology 2030 Strategy focus this science and technology toward, but not limited to, the following capabilities: 1) global persistent awareness; 2) resilient information sharing; 3) rapid, effective decision-making; 4) complexity, unpredictability, and mass; and 5) speed and reach of disruption and lethality.</p> <p><i>FY 2020 OCO Plans:</i> Not applicable</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i></p>	0.000	0.000	19.667	0.000	19.667

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602204F / <i>Aerospace Sensors</i>	Project (Number/Name) 627622 / <i>RF Sensors and Countermeasures Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 increased compared to FY 2019 by \$19.667 million. Funding increased due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.					
Accomplishments/Planned Programs Subtotals	50.437	55.377	52.066	0.000	52.066
	FY 2018	FY 2019			
Congressional Add: Program increase - research by minority leaders program	2.468	0.000			
FY 2018 Accomplishments: Conducted Congressionally directed efforts					
FY 2019 Plans: Not Applicable					
Congressional Add: Program increase - Air Force Minority Leaders Program	0.000	5.000			
FY 2018 Accomplishments: Not applicable					
FY 2019 Plans: Conduct Congressionally directed efforts					
Congressional Adds Subtotals	2.468	5.000			

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602212F / <i>Defense Laboratories R&D Projects (10 U.S.C, Sec 2358)</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	74.760	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Continuing	Continuing
622030: <i>Defense Lab R&D Projects</i>	-	74.760	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Continuing	Continuing

A. Mission Description and Budget Item Justification

Implementation of 10 U.S.C. Section 2363, amendment to PL 110-417, 10 U.S.C. Section 2358 and 10 U.S.C. 2805(d)(1)(B), to fund: innovative basic and applied research conducted at the defense laboratory and supports military missions; development programs supporting the transition of technologies developed by the defense laboratory into operational use; workforce development activities improving the capacity of the defense laboratory to recruit and retain personnel with necessary scientific and engineering expertise that support military missions; and the repair or minor military construction of the laboratory infrastructure and equipment.

The Air Force is dependent on technological advances in response to emerging threats and to maintain a competitive advantage. Air Force has a comprehensive and deliberative planning process to identify and fund research that is expected to have the greatest benefit to the Air Force and the warfighter. 10 U.S.C. Section 2363 provides the Commander of the Air Force Research Laboratory (AFRL), in consultation with the Air Force Science and Technology (S&T) Executive, a degree of flexibility to rapidly exploit scientific breakthroughs or respond to emerging threats, to include developing a skilled workforce and necessary infrastructure. This flexibility increases the rate of innovation and accelerates the development and fielding of needed military capabilities to address current and future problems.

The Air Force has established PE 0602212F, where the 10 U.S.C. Section 2363 funds are internally reprogrammed to this program element in the year of execution after receipt of the appropriation. This allows increased transparency to Congress on 10 U.S.C. Section 2363 funding and additional execution flexibility for 10 U.S.C. Section 2363 activities to cross all technology areas.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research	R-1 Program Element (Number/Name) PE 0602212F I Defense Laboratories R&D Projects (10 U.S.C, Sec 2358)
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	0.000	0.000	0.000	0.000	0.000
Current President's Budget	74.760	0.000	0.000	0.000	0.000
Total Adjustments	74.760	0.000	0.000	0.000	0.000
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• Other Adjustments	74.760	0.000	0.000	0.000	0.000

Change Summary Explanation

Increase in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358, as amended by 10 U.S.C. 2805(d)(1)(B) and 10 U.S.C. Section 2363.

C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Title: Defense Laboratories R&D Projects - Air Force Research Laboratory	74.760	0.000	0.000
Description: Implementation of 10 U.S.C. Section 2363, amendment to PL 110-417, 10 U.S.C. Section 2358 and 10 U.S.C. 2805(d)(1)(B), to fund: innovative basic and applied research conducted at the Air Force Research Laboratory (AFRL) and supports military missions; development programs supporting the transition of technologies developed by AFRL into operational use; workforce development activities improving the capacity of AFRL to recruit and retain personnel with necessary scientific and engineering expertise that support military missions; and the repair or minor military construction of the laboratory infrastructure and equipment.			
FY 2019 Plans: The budget for this program is implemented after an appropriation is passed as directed in provisions of 10 U.S.C. Section 2363.			
FY 2020 Plans: Not Applicable			
FY 2019 to FY 2020 Increase/Decrease Statement: Not Applicable			
Accomplishments/Planned Programs Subtotals	74.760	0.000	0.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force Date: February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research	R-1 Program Element (Number/Name) PE 0602212F I Defense Laboratories R&D Projects (10 U.S.C, Sec 2358)
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D. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

E. Acquisition Strategy

Not Applicable

F. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602298F / <i>Science and Technology Management - Major Headquarters Activities</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	8.353	8.288	7.968	0.000	7.968	8.101	8.271	8.445	8.622	Continuing	Continuing
622520: <i>Science and Technology Management - Major HQ</i>	-	8.353	8.288	7.968	0.000	7.968	8.101	8.271	8.445	8.622	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Air Force Research Laboratory (AFRL) is a global technical enterprise, boasting some of the best and brightest leaders in the world. It provides revolutionary, relevant, and responsive science and technology (S&T) to the Warfighter. AFRL's mission is to lead the discovery, development, and integration of affordable warfighting technologies for the global air, space, and cyberspace force.

In FY 2018, PE 0602298F, Science and Technology Management - Major Headquarters Activities, Project 622520, Science and Technology Management - Major HQ, was established to provide increased transparency to Congress on personnel in Major Headquarters Activities (MHA). A portion of HQ AFRL civilian manpower was transferred into this PE from the following Air Force S&T RDT&E PEs: 0601102F, Basic Research; 0602102F, Materials; 0602201F, Aerospace Vehicle Technologies; 0602203F, Aerospace Propulsion; 0602204F, Aerospace Sensors; 0602601F, Space Technology; 0602602F, Conventional Munitions; 0602605F, Directed Energy Technology; and 0602788F, Dominant Information Sciences and Methods. This was an administrative realignment and not a new start. Prior year funding in this exhibit was previously budgeted in the Air Force S&T RDT&E PEs listed above.

This program element includes necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, and 1206601F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602298F / <i>Science and Technology Management - Major Headquarters Activities</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	8.353	8.288	8.302	0.000	8.302
Current President's Budget	8.353	8.288	7.968	0.000	7.968
Total Adjustments	0.000	0.000	-0.334	0.000	-0.334
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• Other Adjustments	0.000	0.000	-0.334	0.000	-0.334

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602298F / <i>Science and Technology Management - Major Headquarters Activities</i>	Project (Number/Name) 622520 / <i>Science and Technology Management - Major HQ</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622520: <i>Science and Technology Management - Major HQ</i>	-	8.353	8.288	7.968	0.000	7.968	8.101	8.271	8.445	8.622	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Air Force Research Laboratory (AFRL) is a global technical enterprise, boasting some of the best and brightest leaders in the world. It provides revolutionary, relevant, and responsive science and technology (S&T) to the Warfighter. AFRL's mission is to lead the discovery, development, and integration of affordable warfighting technologies for the global air, space, and cyberspace force.

In FY 2018, PE 0602298F, Science and Technology Management - Major Headquarters Activities, Project 622520, Science and Technology Management - Major HQ, was established to provide increased transparency to Congress on personnel in Major Headquarters Activities (MHA). A portion of HQ AFRL civilian manpower was transferred into this PE from the following Air Force S&T RDT&E PEs: 0601102F, Basic Research; 0602102F, Materials; 0602201F, Aerospace Vehicle Technologies; 0602203F, Aerospace Propulsion; 0602204F, Aerospace Sensors; 0602601F, Space Technology; 0602602F, Conventional Munitions; 0602605F, Directed Energy Technology; and 0602788F, Dominant Information Sciences and Methods. This was an administrative realignment and not a new start.

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Title: AFRL - Major Headquarters Activities	8.353	8.288	7.968
Description: Provide professional government civilian workforce in support of all AFRL programs and activities.			
FY 2019 Plans: Provide professional government civilian workforce in support of all AFRL programs and activities.			
FY 2020 Plans: Continue to provide professional government civilian workforce in support of all AFRL programs and activities.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.320 million. Funding decreased due to civilian pay reprice adjustment.			
Accomplishments/Planned Programs Subtotals	8.353	8.288	7.968

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602298F / <i>Science and Technology Management - Major Headquarters Activities</i>	Project (Number/Name) 622520 / <i>Science and Technology Management - Major HQ</i>

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	145.921	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	145.921
621010: <i>Space Survivability & Surveillance</i>	-	38.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	38.300
624846: <i>Spacecraft Payload Technologies</i>	-	25.402	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25.402
625018: <i>Spacecraft Protection Technology</i>	-	21.348	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	21.348
628809: <i>Spacecraft Vehicle Technologies</i>	-	60.871	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	60.871

A. Mission Description and Budget Item Justification

This program focuses on four major areas. First, the space survivability and surveillance area develops technologies to understand space weather and the geophysics environment for mitigation and exploitation of these effects to Air Force systems. Second, the spacecraft payload technologies area improves satellite payload operations by developing advanced component and subsystem capabilities. Third, the spacecraft protection area develops technologies for protecting United States space assets in potential hostile settings. The last major area, spacecraft vehicles, focuses on spacecraft platform and control technologies, and their interactions. Efforts in this program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

In FY 2019, the entirety of PE 0602601F, Space Technology, transfers to PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	116.503	0.000	0.000	0.000	0.000
Current President's Budget	145.921	0.000	0.000	0.000	0.000
Total Adjustments	29.418	0.000	0.000	0.000	0.000
• Congressional General Reductions	-0.126	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	32.100	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-2.556	0.000			
• Other Adjustments	0.000	0.000	0.000	0.000	0.000

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 624846: *Spacecraft Payload Technologies*

Congressional Add: *Program increase*

Congressional Add Subtotals for Project: 624846

Project: 628809: *Spacecraft Vehicle Technologies*

Congressional Add: *Program increase - spacecraft vehicle technologies*

Congressional Add: *Small satellites for resiliency and augmentation of space architecture*

Congressional Add Subtotals for Project: 628809

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	9.828	0.000
Congressional Add Subtotals for Project: 624846	9.828	0.000
	2.457	0.000
Congressional Add Subtotals for Project: 628809	21.720	0.000
Congressional Add Totals for all Projects	31.548	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>				Project (Number/Name) 621010 / <i>Space Survivability & Surveillance</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
621010: <i>Space Survivability & Surveillance</i>	-	38.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	38.300

A. Mission Description and Budget Item Justification

This project develops technologies to understand and control the space environment for warfighter's future capabilities. The focus is on characterizing and forecasting the battlespace environment for more realistic space system design, modeling, and simulation, as well as the battlespace environment's effect on space systems' performance. This includes technologies to specify and forecast the space environment for planning operations, ensure uninterrupted system performance, optimize space-based surveillance operations, and provide capability to mitigate or exploit the space environment for both offensive and defensive operations. Finally, this project includes the seismic research program that supports national requirements for monitoring nuclear explosions.

For FY 2019 and beyond, the entirety of the Project 621010, Space Survivability and Surveillance, is reported under PE 1206601F, Space Technology, Project 621010, Space Survivability and Surveillance. This administrative transfer provides increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Space Environment Research</p> <p>Description: Develop techniques, forecasting tools, sensors, and technologies for specifying, monitoring, predicting, and controlling space environmental conditions hazardous to Department of Defense operational space and radar systems.</p> <p>FY 2019 Plans: For FY 2019, this work is performed under the Space Environment Research effort in PE 1206601F, Space Technology, Project 621010, Space Survivability & Surveillance.</p> <p>FY 2020 Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable</p>	12.660	0.000	0.000
<p>Title: Surveillance Technologies</p> <p>Description: Develop advanced target detection techniques, spectral signature libraries, and decision aids for space-based sensors and surveillance systems.</p> <p>FY 2019 Plans:</p>	8.202	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>	Project (Number/Name) 621010 / <i>Space Survivability & Surveillance</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
For FY 2019, this work is performed under the Surveillance Technologies effort in PE 1206601F, Space Technology, Project 621010, Space Survivability & Surveillance. FY 2020 Plans: Not applicable FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable				
Title: Radiation Remediation Research Description: Conduct Radiation Belt Remediation research through development and validation of analytical performance models for remediation of Earth radiation belts following high altitude nuclear detonation. FY 2019 Plans: For FY 2019, this work is performed under the Radiation Remediation Research effort in PE 1206601F, Space Technology, Project 621010, Space Survivability & Surveillance. FY 2020 Plans: Not applicable FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable		2.625	0.000	0.000
Title: Seismic Technologies Description: Develop seismic technologies to support national requirements for monitoring nuclear explosions with special focus on regional distances less than 2,000 kilometers from the sensors. FY 2019 Plans: For FY 2019, this work is performed the under the Seismic Technologies effort in PE 1206601F, Space Technology, Project 621010, Space Survivability & Surveillance. FY 2020 Plans: Not applicable FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable		6.281	0.000	0.000
Title: Alternative Navigation Technologies		8.532	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>	Project (Number/Name) 621010 / <i>Space Survivability & Surveillance</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Description: Develop new technologies based on cold atom physics that provide autonomous jam-proof precision inertial navigation to augment Global Positioning System in case of Global Positioning System-denial. Develop atomic clocks based on new technologies to replace legacy Global Positioning System atomic clocks.</p> <p>FY 2019 Plans: For FY 2019, this work is performed under Alternative Navigation Technologies effort in PE 1206601F, Space Technology, Project 621010, Space Survivability & Surveillance.</p> <p>FY 2020 Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable</p>			
Accomplishments/Planned Programs Subtotals	38.300	0.000	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>				Project (Number/Name) 624846 / <i>Spacecraft Payload Technologies</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624846: <i>Spacecraft Payload Technologies</i>	-	25.402	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25.402

A. Mission Description and Budget Item Justification

This project develops advanced technologies that enhance spacecraft payload operations by improving component and subsystem capabilities. The project focuses on development of advanced, space-qualified, survivable electronics, and electronics packaging technologies; development of advanced space data generation and exploitation technologies, including infrared sensors; and development of high-fidelity space simulation models that support space-based surveillance and space asset protection research and development for the warfighter.

In FY 2019, the entirety of Project 624846, Spacecraft Payload Technologies is reported under PE 1206601F, Space Technology, Project 624846, Spacecraft Payload Technologies. This administrative transfer provides increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Space-Based Detector Technologies</p> <p>Description: Develop advanced infrared device technologies that enable hardened space detector arrays with improved detection to perform acquisition, tracking, and discrimination of space objects and missile warning.</p> <p>FY 2019 Plans: For FY 2019, this work is performed under the Space-Based Detector Technologies effort in PE 1206601F, Space Technology, Project 624846, Spacecraft Payload Technologies.</p> <p>FY 2020 Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable</p>	3.235	0.000	0.000
<p>Title: Space Electronics Research</p> <p>Description: Develop technologies for space-based payload components such as radiation-hardened electronic devices, micro-electro-mechanical system devices, and advanced electronics packaging.</p> <p>FY 2019 Plans:</p>	2.669	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>	Project (Number/Name) 624846 / <i>Spacecraft Payload Technologies</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
For FY 2019, this work is performed under the Space Electronics Research effort in PE 1206601F, Space Technology, Project 624846, Spacecraft Payload Technologies.				
FY 2020 Plans: Not applicable				
FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable				
Title: Modeling and Simulation Tools for Space Applications		5.216	0.000	0.000
Description: Develop modeling and simulation tools for space-based ground surveillance systems, rendezvous and proximity operations, imaging of space systems, disaggregated satellite architecture, and space control payloads.				
FY 2019 Plans: For FY 2019, this work is performed under the Modeling and Simulation Tools for Space Applications effort in PE 1206601F, Space Technology, Project 624846, Spacecraft Payload Technologies.				
FY 2020 Plans: Not applicable				
FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable				
Title: Alternative Positioning, Navigation, and Timing Technology		4.454	0.000	0.000
Description: Identify and develop technologies that enable new, or enhance existing, United States positioning, navigation, and timing satellite capabilities by increasing resiliency and availability of accuracy, and/or increasing the affordability of providing current capabilities. Develop technologies to meet identified Air Force Space Command/Space and Missile Systems Center positioning, navigation, and timing space payload technology needs.				
FY 2019 Plans: For FY 2019, this work is performed under the Alternative Positioning, Navigation, and Timing Technology effort in PE 1206601F, Space Technology, Project 624846, Spacecraft Payload Technologies.				
FY 2020 Plans: Not applicable				
FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable				
Accomplishments/Planned Programs Subtotals		15.574	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>	Project (Number/Name) 624846 / <i>Spacecraft Payload Technologies</i>
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	FY 2018	FY 2019
Congressional Add: Program increase	9.828	0.000
FY 2018 Accomplishments: Conducted Congressionally directed effort		
FY 2019 Plans: Not applicable		
Congressional Adds Subtotals	9.828	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>				Project (Number/Name) 625018 / <i>Spacecraft Protection Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625018: <i>Spacecraft Protection Technology</i>	-	21.348	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	21.348

A. Mission Description and Budget Item Justification

This project develops the technologies for protecting United States space assets in potentially hostile environments to assure continued space system operation without performance loss in support of warfighter requirements. The project focuses on identifying and assessing spacecraft system vulnerabilities, developing threat warning technologies, and developing technologies to mitigate the effects of both intentional and unintentional threats.

In FY 2019, the entirety of Project 625018, Spacecraft Protection Technology is reported under PE 1206601F, Space Technology, Project 625018, Spacecraft Protection Technology. This administrative transfer provides increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Threat Warning Research	21.348	0.000	0.000
Description: Develop satellite threat warning technologies and tools for space defense. Exploit on-board inherent satellite resources, satellite-as-a-sensor, and self-aware satellite technologies. Develop technologies to detect, assess, and respond to threats and anomalies.			
FY 2019 Plans: For FY 2019, this work is performed under the Threat Warning Research effort in PE 1206601F, Space Technology, Project 625018, Spacecraft Protection Technology.			
FY 2020 Plans: Not applicable			
FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable			
Accomplishments/Planned Programs Subtotals	21.348	0.000	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>	Project (Number/Name) 625018 / <i>Spacecraft Protection Technology</i>
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D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602601F / Space Technology				Project (Number/Name) 628809 / Spacecraft Vehicle Technologies			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
628809: Spacecraft Vehicle Technologies	-	60.871	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	60.871

A. Mission Description and Budget Item Justification

This project focuses on spacecraft platforms (for example, structures, power, and thermal management); satellite control (such as, signal processing and control); and space experiments of maturing technologies for space qualification.

In FY 2019, the entirety of Project 628809, Spacecraft Vehicle Technologies, is reported under PE 1206601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies. This administrative transfer provides increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Space Power/Thermal Research</p> <p>Description: Develop technologies for advanced space platform subsystems such as cryocoolers, compact, high efficiency solar power cells and arrays, and innovative power generation concepts.</p> <p>FY 2019 Plans: For FY 2019, this work is performed under the Space Power/Thermal Research effort in PE 1206601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies.</p> <p>FY 2020 Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable</p>	6.160	0.000	0.000
<p>Title: Space Structures and Controls Research</p> <p>Description: Develop revolutionary and enabling technologies, including lighter weight, lower cost, high performance structures for space platforms; guidance, navigation, and controls hardware and software for next generation of space superiority systems.</p> <p>FY 2019 Plans: For FY 2019, this work is performed under the Space Structures and Controls Research effort in PE 1206601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies.</p> <p>FY 2020 Plans:</p>	11.553	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019	
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>	Project (Number/Name) 628809 / <i>Spacecraft Vehicle Technologies</i>	
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019
Not applicable			
FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable			
Title: Space Experiments		12.180	0.000
Description: Develop flight experiments to improve the capabilities of existing operational space systems and to enable new transformational space capabilities.			
FY 2019 Plans: For FY 2019, this work is performed under the Space Experiments effort in PE 1206601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies.			
FY 2020 Plans: Not applicable			
FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable			
Title: Space Communication Technologies		9.258	0.000
Description: Develop technologies for next-generation space communications terminals and equipment and methods/techniques to enable future space system operational command and control concepts.			
FY 2019 Plans: For FY 2019, this work is performed under the Space Communication Technologies effort in PE 1206601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies.			
FY 2020 Plans: Not applicable			
FY 2019 to FY 2020 Increase/Decrease Statement: Not applicable			
Accomplishments/Planned Programs Subtotals		39.151	0.000
		FY 2018	FY 2019
Congressional Add: Program increase - spacecraft vehicle technologies		2.457	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602601F / <i>Space Technology</i>	Project (Number/Name) 628809 / <i>Spacecraft Vehicle Technologies</i>
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	FY 2018	FY 2019
<i>FY 2018 Accomplishments:</i> Conducted Congressionally directed effort		
<i>FY 2019 Plans:</i> Not applicable		
<i>Congressional Add:</i> Small satellites for resiliency and augmentation of space architecture	19.263	0.000
<i>FY 2018 Accomplishments:</i> Conducted Congressionally directed effort		
<i>FY 2019 Plans:</i> Not applicable		
Congressional Adds Subtotals	21.720	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602602F <i>I Conventional Munitions</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	99.543	112.841	142.772	0.000	142.772	150.085	165.801	144.606	147.611	Continuing	Continuing
622068: <i>Advanced Guidance Technology</i>	-	47.273	57.513	80.641	0.000	80.641	83.562	90.307	69.979	71.433	Continuing	Continuing
622502: <i>Ordnance Technology</i>	-	52.270	55.328	62.131	0.000	62.131	66.523	75.494	74.627	76.178	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program investigates, develops, and establishes the technical feasibility and military utility of guidance and ordnance technologies for conventional air-launched munitions. The effort supports core technical competencies of fuze technology; energetic materials; damage mechanisms; munitions aerodynamics, guidance, navigation, and control; terminal seeker sciences; and munition systems effects. Technologies to be developed include blast, fragmentation, penetrating and low-collateral damage war-heads, hard-target fuzing, precise terminal guidance, and high-performance and insensitive explosives.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	112.195	112.841	129.393	0.000	129.393
Current President's Budget	99.543	112.841	142.772	0.000	142.772
Total Adjustments	-12.652	0.000	13.379	0.000	13.379
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-5.800	0.000			
• SBIR/STTR Transfer	-1.889	0.000			
• Other Adjustments	-4.963	0.000	13.379	0.000	13.379

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

Decrease in FY 2018 due to \$5.800 million reprogramming action of funds to PE 0603601F, Conventional Weapons Technology, for hypersonic weapon technology.

Increase in FY 2020 due to civilian pay re-pricing adjustment and realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>				Project (Number/Name) 622068 / <i>Advanced Guidance Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622068: <i>Advanced Guidance Technology</i>	-	47.273	57.513	80.641	0.000	80.641	83.562	90.307	69.979	71.433	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project investigates, develops, and evaluates conventional munitions guidance technologies to establish technical feasibility and military utility of innovative munition seekers, weapon aerodynamics, navigation and control, and guidance subsystem integration/simulation. Project payoffs include adverse-weather, Global Positioning System (GPS)-degraded and Global Positioning System-denied, networked, and autonomous precision munition guidance capability; increased number of kills per sortie; increased aerospace vehicle survivability; improved weapon reliability and affordability; and improved weapon survivability and effectiveness.

B. Accomplishments/Planned Programs (\$ in Millions)

<p>Title: Seeker Technologies</p> <p>Description: Develops seeker technologies for air-delivered munitions to provide high-confidence target discrimination and classification, precise target location, and robust terminal tracking.</p> <p>FY 2019 Plans: Continue to emphasize technology development of multi-function sensors, rapid data compression for targeting, bio-inspired information processing and data fusion, and low-power computation. Continue to develop technologies that simplify, increase flexibility, and reduce the cost of advanced seeker concepts. Continue to develop algorithmic and mathematical approaches to integrate weapons into the kill chain and enable distributive, flexible seeker imaging targeting with or without an operator in the loop. Continue development and testing of innovative air-to-air engagements for fifth generation and beyond. Continue to explore incorporation of open architecture principles to reduce cost and enable technology refresh within seeker subsystems. Continue to develop distributed, low-cost seeker technology hardware. Continue to explore specific techniques for seeker cost reduction with performance improvement; novel technical approaches such as sparse sensing and compressive sensing will be investigated. Continue to conduct research on integrated processing techniques to enable networked systems. Continue development and early testing of small, air-to-air, self-defense munitions seeker technology including initial captive flight testing and hardware in the loop testing. Continue to develop open seeker architecture software in the loop integration laboratory. Initiate the investigation of the technical challenges of cooperative radio frequency functions including coherent on transmit and coherent on receive operation. Initiate software development kit for Open Seeker Architecture to enable rapid technology insertion into software-defined, multi-function seekers. Initiate the development of tools for evaluation of deep-learning networks to evaluate feasibility for weapon seekers. Initiate exploration of Open Architecture systems' cyber vulnerabilities and formulate software resilient techniques. Initiate data collection experiments to support cooperative radio frequency systems.</p> <p>FY 2020 Plans:</p>	FY 2018	FY 2019	FY 2020
	4.485	6.643	9.416

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622068 / <i>Advanced Guidance Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Continue to emphasize technology development of multi-function sensors, rapid data compression for targeting, bio-inspired information processing and data fusion, and low-power computation. Continue to develop technologies that simplify, increase flexibility and reduce the cost of advanced seeker concepts to include biologically inspired low-cost concepts. Continue to develop algorithmic and mathematical approaches to integrate weapons into the kill chain to enable distributive, flexible seeker imaging targeting with or without an operator in-the-loop. Continue development and testing of innovative air-to-air engagements for fifth generation and beyond with emphasis on radome materials that improve optical performance, as well as provide increased protection from operational environments including directed energy and rain. Continue to explore incorporation of open architecture principles to reduce cost and enable technology refresh within seeker subsystems. Continue to explore specific techniques for seeker cost reduction with performance improvement; novel technical approaches such as sparse and compressive sensing will be investigated. Continue to conduct research on integrated processing techniques to enable networked systems to include early collaborative global positioning system denied navigation and miniature self-defense seeker design. Continue to develop open seeker architecture software in-the-loop integration laboratory. Continue to investigate the technical challenges of cooperative radio frequency functions including coherent on-transmit/on-receive operation. Continue to refine the software development kit for Open Seeker Architecture to enable rapid technology insertion into software-defined, multi-function seekers. Continue to refine and further development of tools for evaluation of deep-learning networks to evaluate feasibility for weapon seekers. Continue analysis of Open Seeker Architecture cyber vulnerabilities and formulate software resilient techniques. Continue data collection experiments to support cooperative radio frequency systems.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$2.773 million. Funding increased due to development of additional modeling tools, enhanced seeker design fidelity, and expansion of cyber vulnerability analysis.</p>			
<p>Title: Aerodynamics, Navigation, and Control Technologies</p> <p>Description: Develops weapon aerodynamic control, navigation, and networking technologies for air-delivered munitions to provide precise, agile flight, networked effects, and immunity to countermeasures.</p> <p>FY 2019 Plans: Continue the maturation of linked aero-structural-thermal computational tools to predict flight performance of hypersonic weapons and tools to develop prototype concepts for program office prototype demonstrations. Continue to refine and demonstrate via captive and surrogate flight test, a precision navigation method that does not rely on GPS and includes an M-Code compliant anti-jam GPS chip set. Continue development of weapon platform interfaces to include concepts for double increased weapons load-out. Continue the integration of algorithms to support distributed, multi-strategy weapon concept-of-operations to defeat enemy defenses to include data link information to bound drift of a swarm of weapons. Continue ground testing of advanced guidance laws and actuators to enable innovative air-to-air engagements and hyper-agility including hit-to-kill. Continue conducting experiments demonstrating precision navigation using celestial aiding for long-range flights at high and low altitudes. Continue small, air-to-air, self-defense munitions research efforts. Initiate cooperative/collaborative small cruise missile swarm</p>	27.162	28.544	29.367

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622068 / <i>Advanced Guidance Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>flight demonstration to locate and overwhelm targets. Initiate planning for flight test of a multi-vehicle mapping without Global Positioning System and saturation approach of the entrance of a hardened deeply buried facility or tunnel target. Initiate and conduct ground tests of rocket motor component technologies to evaluate their ability to increase weapon range and reduce size/weight. Initiate the development of defensive cyber algorithms for autopilot and navigation functions, including swarm. Initiate execution of Joint Capability Technology Demonstration program with system program office and Combatant Command user for Global Position System-denied navigation suite for cruise missiles. Initiate efforts to identify cyber vulnerabilities in software define radios used on weapons by testing meshing radios. Initiate munition cyber-hardening demonstration coordinated with Cyber Command and extend to an integrated systems test environment. Initiate intramural Air Force study of high fidelity models for store separation from aircraft using advanced dispense technologies.</p> <p>FY 2020 Plans: Complete and transitioned the hypersonic flight performance aero-structural-thermal computational tools and prototype concept development tools to the program office. Complete the integration of algorithms to support distributed, multi-strategy weapon concept-of-operations to defeat enemy defenses. Continue execution of Position, Navigation and Timing acceleration research to integrate emitter geo-location and Electronic Intelligence into M-Code compliant anti-jam Global Position System chip set. Continue development of weapon platform interfaces to include concepts for double increased weapons load-out. Continue ground testing of advanced guidance laws and actuators to enable innovative air-to-air engagements and hyper-agility including hit-to-kill. Continue experiments demonstrating precision navigation using celestial aiding for long-range flights at high and low altitudes. Continue small, air-to-air, self-defense munitions research efforts. Continue cooperative/collaborative small cruise missile swarm flight demonstration to locate and overwhelm targets. Continue flight test of a multi-vehicle mapping (without Global Positioning System) and saturation approach of the entrance of a hardened-deeply-buried facility or tunnel target. Continue ground tests of rocket motor component technologies to evaluate their ability to increase weapon range and reduce size/weight. Continue development of defensive cyber algorithms for autopilot and navigation functions, including swarm. Continue execution of Joint Capability Technology Demonstration program with system program office and Combatant Command user for Global Position System-denied navigation suite for cruise missiles. Continue efforts to identify cyber vulnerabilities in software define radios used on weapons by testing meshing radios. Continue munition cyber-hardening demonstration coordinated with Cyber Command and extend to an integrated systems test environment. Continue intramural Air Force study of high fidelity models for store separation from aircraft using advanced dispense technologies. Initiate trade study of low-cost navigation grade Inertial Measurement Units, build weapon Size-Weight-And-Power celestial aiding sensor for upcoming high-altitude hypersonic test, use tactical software defined radio to flight test network aiding using meshing waveform. Initiate scaled flight demonstrations of advanced guidance laws for self-defense and multi-shot air-to-air missiles.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.823 million. Justification for this increase is described in the plans above.</p>			
Title: Guidance Technologies	15.626	22.326	22.192

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622068 / <i>Advanced Guidance Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Description: Develops guidance subsystem integration and evaluation technologies to provide open and closed-loop ground testing, flight test risk reduction, and digital simulation of novel concepts.</p> <p>FY 2019 Plans: Continue to support flight demonstrations of critical behaviors for distributed collaborative and cooperative swarm strategies and other advanced guidance capabilities by improving constructive and virtual analysis tools for design, development, and analysis of advanced weapon concepts in representative environments. Continue to perform constructive and virtual analysis on numerous weapon concepts providing design, performance, and trade space analysis to the program offices. Continue to develop improved simulation technologies that evaluate innovative air-to-air engagements to include guidance evaluation. Continue to develop a real-time radar/millimeter wave signature generation capability for testing algorithms in real-time software and hardware-in-the-loop environments. Continue to develop simulation technologies that evaluate cooperative, flexible munition target engagements. Continue to transition refined engineering models to Air Force mission level simulation for analysis. Continue to develop a modular radio-frequency hardware-in-the-loop capability to support munitions concepts with high speed target engagement. Continue to improve capabilities of our reconfigurable radio-frequency hardware-in-the-loop chamber to handle faster and more complex scenes. Continue to develop new infrared projection capabilities to evaluate a new class of multi-aperture sensor systems. Initiate and complete the startup of a Modeling and Simulation activity enabling cross-domain, distributed, multi-level security Modeling and Simulation. Initiate a help desk and configuration control of higher fidelity simulation codes for mission level analysis. Initiate constructive and virtual analysis on numerous weapon concepts to provide design, performance, and trade space analysis to the program offices.</p> <p>FY 2020 Plans: Complete transition of reconfigurable Radio Frequency Target Simulator to prime contractors to support hypersonic weapon development. Complete and refine the Modeling and Simulation capability with multi-level security enabling cross-domain, distributed Modeling and Simulation activities. Continue flight demonstration of critical behaviors for Distributed, Cooperative, Collaborative strategies and other advanced guidance capabilities. Continue to improve constructive and virtual analysis tools for design, development, and analysis of advanced cruise missile concepts in representative environments and provide design, performance, and trade space analysis for hypersonic and air-to-air weapon concepts to the program offices. Continue to improve simulation technologies that evaluate innovative air-to-air and air-to-surface engagements to include guidance and control evaluation. Continue to develop a real-time radar/millimeter wave signature generation capability for testing algorithms in real-time software and hardware-in-the-loop environments to include additional targets and improved terrain resolution to multi-spectral signature generation capability for testing algorithms in real-time software and hardware in-the-loop environments. Continue to develop simulation technologies that evaluate cooperative, flexible munition target engagements. Continue to transition refined engineering models to Air Force mission level simulation for analysis. Continue to improve capabilities of our reconfigurable radio-frequency hardware-in-the-loop chamber to handle faster and more complex scenes to include demonstrating real-time fluid thermal structural interaction effects during hardware-in-the-loop simulation of hypersonic weapons. Continue to develop new</p>			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622068 / <i>Advanced Guidance Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>infrared projection capabilities to evaluate a new class of multi-aperture sensor systems to include demonstrating increased scene complexity and closed-loop real-time interface and high-density Infrared Light Emitting Diode array with improved performance. Continue development of "help desk" high-fidelity modeling and scene generation modules for the extended modeling and simulation community using Air Force Simulation. Continue constructive and virtual analysis on numerous weapon concepts to provide design, performance, and trade space analysis to the program offices. Initiate refurbishment of main Kinetic Hardware-In-the-Loop System facility. Initiate distributed connectivity capability between multiple Air Force facilities for cross-domain, distributed, multi-level security modeling and simulation activities.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.134 million. Justification for the decrease is described in the plans above.</p>				
<p>Title: Future AF Capabilities Applied Research</p> <p>Description: Investigate, design, and develop science and technologies supporting future Air Force capabilities to provide compelling advantage to the warfighter. To the greatest extent practical, research efforts will utilize modeling and simulation and cross-discipline systems integration (For example: air and space vehicles, avionics, propulsion, materials, human performance, cybersecurity, command, control, communications, computer and intelligence, sensors, electronic warfare, and conventional/unconventional weapons).</p> <p>The National Defense Strategy and Air Force Science and Technology 2030 Strategy will inform investments over the FYDP.</p> <p>FY 2019 Plans: In FY 2019, this work is performed under multiple projects and efforts within the following Air Force Scientific and Technology programs: 0602102F, Materials; 0602201F, Aerospace Vehicle Technologies; 0602202F, Human Effectiveness Applied Research; 0602203F, Aerospace Propulsion; 0602204F, Aerospace Sensors; 1206601F, Space Technology; 0602602F, Conventional Munitions; 0602605F, Directed Energy Technology; and 0602788F, Dominant Information Science and Methods.</p> <p>FY 2020 Plans: Continue to investigate and mature science and technology that enables future warfighting concepts to provide leap-ahead capabilities. The National Defense Strategy and Air Force Science and Technology 2030 Strategy focus this science and technology toward, but not limited to, the following capabilities: 1) global persistent awareness; 2) resilient information sharing; 3) rapid, effective decision-making; 4) complexity, unpredictability, and mass; and 5) speed and reach of disruption and lethality.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$19.666 million. Funding increased to due the re-alignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.</p>		-	0.000	19.666
Accomplishments/Planned Programs Subtotals		47.273	57.513	80.641

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force Date: February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622068 / <i>Advanced Guidance Technology</i>
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C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not Applicable

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>				Project (Number/Name) 622502 / <i>Ordnance Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
622502: <i>Ordnance Technology</i>	-	52.270	55.328	62.131	0.000	62.131	66.523	75.494	74.627	76.178	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project investigates, develops, and evaluates conventional ordnance technologies to establish technical feasibility and military utility for advanced explosives, fuzes, warheads, sub-munitions, and weapon airframes, carriage, and dispensing. The project also assesses the lethality and effectiveness of current and planned conventional weapons technology programs and assesses target vulnerability. The payoffs include improved storage capability and transportation safety of fully assembled weapons, improved warhead and fuze effectiveness, improved sub-munitions dispensing, low-cost airframe/subsystem components and structures, and reduced aerospace vehicle and weapon drag.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Energetic Materials Technology	2.421	2.992	3.509
Description: Investigates and develops energetic materials and technology that safely and securely optimize survivability, cost, and weapon lethality for air-delivered munitions.			
FY 2019 Plans: Continue to mature and develop selected energetic materials to increase energy density over that of traditional explosives while enhancing damage mechanisms and lethality for mass and volume-constrained applications. Continue to build and implement experimental techniques/capabilities to quantify dynamic and mechanical properties as well as survivability of energetic materials in extreme temperature and vibrational environments. Continue to develop theoretical and virtual formulation and processing techniques for energetic materials and provide the second release of the tool/software to the energetics community. Continue to develop tools and analysis techniques to further understanding of energy partitioning in order to optimize lethality against a broad spectrum of targets. Continue to formulate and test liner technologies to improve Insensitive Munitions performance. Continue to mature additive manufacturing techniques to increase the design space for kinetic weapon lethality.			
FY 2020 Plans: Continue to mature and develop selected energetic materials to increase energy density over that of traditional explosives while enhancing damage mechanisms and lethality for mass and volume-constrained applications. Continue to build and implement experimental techniques/capabilities to quantify dynamic and mechanical properties as well as survivability of energetic materials in extreme temperature and vibrational environments. Continue to develop theoretical and virtual formulation and processing techniques for energetic materials and provide the second release of the tool/software to the energetics community. Continue to develop tools and analysis techniques to further understanding of energy partitioning in order to optimize lethality against a broad spectrum of targets. Continue to formulate and test liner technologies to improve Insensitive Munitions performance. Continue to			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622502 / <i>Ordnance Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
mature additive manufacturing techniques to increase the design space for kinetic weapon lethality. Initiate formulation of novel explosive fill to satisfy severe environmental constraints. Initiate development of large scale nano-energetic material fabrication.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.517 million. Justification for the increase is described in the plans above.				
Title: Fuze Technologies		2.996	4.015	5.303
Description: Investigate and develop fuzing technology for air-delivered weapons to ensure reliable and optimal function to maximize weapon lethality for all engagement scenarios.				
FY 2019 Plans: Continue to develop testing capabilities for munitions penetration scenarios and increase Modeling and Simulation capabilities to reduce research and development costs and time lines. Continue to develop and demonstrate alternative packaging technology for survivable fuze electronic components. Continue to investigate the reliability and survivability of electronic components to predict and measure fuze performance during munition penetration at high-impact speeds. Continue research to facilitate tailored lethal effects and enable optimum fuzing solutions across the spectrum of weapon and target interactions. Continue research for distributed and multi-point fuzing concepts. Continue implementing additive manufacturing techniques to increase fuze reliability.				
FY 2020 Plans: Continue to develop testing capabilities for munitions penetration scenarios and increase Modeling and Simulation capabilities to reduce research and development costs and time lines. Continue to develop and demonstrate alternative packaging technology for survivable fuze electronic components. Continue to investigate the reliability and survivability of electronic components to predict and measure fuze performance during munition penetration at high-impact speeds. Continue research to facilitate tailored lethal effects and enable optimum fuzing solutions across the spectrum of weapon and target interactions. Continue research for distributed and multi-point fuzing concepts. Continue implementing additive manufacturing techniques to increase fuze reliability. Initiate fuze explosive interfaces analysis for robust definition of explosive train reliability and performance. Initiate fuze endgame, active imaging for target detection and aim point selection.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.288 million. Funding increased due to additional research for high-speed fuze system penetrating weapon applicability and enhancement of target detection, aimpoint, and burst-timing calculations for active imaging fuze systems.				
Title: Warhead Technologies		13.501	14.643	16.158
Description: Investigate and develop innovative warhead kill mechanisms for air-delivered weapons that maximize weapon lethality for all engagement scenarios.				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019	
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622502 / <i>Ordnance Technology</i>	
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019
<p><i>FY 2019 Plans:</i> Continue to mature small, multi-output warhead technologies for soft-surface targets, to include limited penetration capability of hardened structures. Continue to evolve test capabilities to enhance quantification of the mechanical response under high-rate, high-pressure loading conditions for use in high fidelity Modeling and Simulation tools, to include materials used in additive manufacturing processes. Continue to develop additive manufacturing techniques and produce optimized sub-scale articles for test. Continue to demonstrate technologies for effective and survivable high-speed penetration into hard targets. Continue to develop air-to-air missile warhead concepts for the air targets in near-peer engagement scenarios. Continue to research and develop cumulative damage mechanisms that take advantage of distributed blast, as well as shock wave and reactive particle interactions. Continue integration of warhead research with related activities planned for the advanced/integrated ordnance subsystems research capability.</p> <p><i>FY 2020 Plans:</i> Continue to mature small, multi-output warhead technologies for soft-surface targets, to include limited penetration capability of hardened structures. Continue to evolve test capabilities to enhance quantification of the mechanical response under high-rate, high-pressure loading conditions for use in high fidelity Modeling and Simulation tools, to include materials used in additive manufacturing processes. Continue to develop additive manufacturing techniques and produce optimized sub-scale articles for test. Continue to demonstrate technologies for effective and survivable high-speed penetration into hard targets. Continue to develop air-to-air missile warhead concepts for the air targets in near-peer engagement scenarios. Continue to research and develop cumulative damage mechanisms that take advantage of distributed blast, as well as shock wave and reactive particle interactions. Continue integration of warhead research with related activities planned for the advanced/integrated ordnance subsystems research capability. Initiate a characterization of Low-Density and High-Density Reactive Materials for use in multi-mission roles. Initiate the development of topological optimization in support of additive manufacturing. Initiate studies of composite based warheads for penetrator/perforator applications.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$1.515 million. Funding increased due to additional research for counter-air warhead concepts, additional test and experimentation for variate-density reactive materials, and enhancement of composite-based warhead application studies.</p>			
<p><i>Title:</i> Ordnance Technologies</p> <p><i>Description:</i> Investigate and develop ordnance sub-system (energetics, fuzes and war-heads) and integrated system concepts using both high-fidelity and fast-running engineering level Modeling and Simulation tools.</p> <p><i>FY 2019 Plans:</i> Complete the development of Modeling and Simulation tools and analysis techniques to understand energy partitioning in order to optimize lethality with a focus on blast wave interactions, cumulative and collaborative damage mechanism behavior, and</p>		33.352	33.678
		37.161	

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622502 / <i>Ordnance Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>distributed blast effects. Continue to develop validated mesoscale Modeling and Simulation tools for computational physics sciences. Continue to mature engineering-level simulation architecture capability to enable weapon sub-system and system-level technology assessments. Continue to implement cost-effective and rapid transition war-head technologies for Air Force inventory penetrator weapons. Continue to conduct Modeling and Simulation that explores the ordnance technology trade space for low-cost, long-range munition concepts. Continue to develop predictive analytic techniques for munition effectiveness tools used in concept development and assessment as well as studies involving analysis of alternatives. Continue to develop test capability and data collection for Modeling and Simulation tools to characterize lethality, survivability and performance of sub-systems and integrated ordnance systems. Complete the development of Modeling and Simulation tools and analysis techniques to understand energy partitioning in order to optimize lethality with a focus on blast wave interactions, cumulative and collaborative damage mechanism behavior, and distributed blast effects.</p> <p><i>FY 2020 Plans:</i> Continue to develop validated mesoscale Modeling and Simulation tools for computational physics sciences. Continue to mature engineering-level simulation architecture capability to enable weapon sub-system and system-level technology assessments. Continue to implement cost-effective and rapid transition war-head technologies for inventory penetrator weapons. Continue to conduct Modeling and Simulation that explores the ordnance technology trade space for low-cost, long-range munition concepts. Continue to develop predictive techniques for munition effectiveness tools used in concept development and assessment as well as studies involving analysis of alternatives. Continue to develop test capability and data collection for Modeling and Simulation tools to characterize lethality, survivability and performance of sub-systems and integrated ordnance systems. Initiate the development of ordnance test and evaluation capabilities that include thermal and vibration management for hypersonic and high-speed flight.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$3.483 million. Funding increased due to improved fidelity of meso-scale modeling tools, higher quality of munitions effectiveness tools, and more robust testing and evaluation of high-speed ordnance and energetic materials.</p>			
Accomplishments/Planned Programs Subtotals	52.270	55.328	62.131

C. Other Program Funding Summary (\$ in Millions)
N/A

Remarks

D. Acquisition Strategy
Not Applicable.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602602F / <i>Conventional Munitions</i>	Project (Number/Name) 622502 / <i>Ordnance Technology</i>

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	121.610	141.800	124.379	0.000	124.379	124.693	127.465	132.446	135.434	Continuing	Continuing
624866: <i>Lasers & Imaging Technology</i>	-	91.384	108.294	92.359	0.000	92.359	88.856	89.562	93.058	95.164	Continuing	Continuing
624867: <i>Advanced Weapons & Survivability Technology</i>	-	30.226	33.506	32.020	0.000	32.020	35.837	37.903	39.388	40.270	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program covers research in Directed Energy (DE) technologies, primarily High Energy Lasers (HEL); including devices; optical beam control; integration; target lethality/vulnerability assessments; ground-based optical Space Situational Awareness (SSA); and high power microwaves (HPM). Laser research includes moderate to high power laser devices that are applicable to a wide range of applications, optical technologies to propagate laser beams through the atmosphere, and integration of these technologies into demonstration packages. Space Situational Awareness research uses the Starfire Optical Range (SOR) and the Maui Space Surveillance System (MSSS) to develop and implement technologies to identify visual characteristics such as status and health of orbiting space objects. In high power microwaves (HPM), this research examines technologies for applications such as counter-electronics and non-lethal weapons. This program conducts research into other novel Directed Energy applications; conducts Directed Energy vulnerability/lethality assessments; develops protection technologies versus Directed Energy; conducts research into other advanced non-conventional/innovative weapons; develops and uses tools to compare solutions to determine the most effective and efficient Directed Energy technologies to meet Air Force needs; coordinates efforts through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	132.993	141.898	133.106	0.000	133.106
Current President's Budget	121.610	141.800	124.379	0.000	124.379
Total Adjustments	-11.383	-0.098	-8.727	0.000	-8.727
• Congressional General Reductions	-0.062	-0.098			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-0.146	0.000			
• SBIR/STTR Transfer	-2.483	0.000			
• Other Adjustments	-8.692	0.000	-8.727	0.000	-8.727

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects 10 U.S.C. Section 2358.

Decrease in FY 2020 due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>				Project (Number/Name) 624866 / <i>Lasers & Imaging Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624866: <i>Lasers & Imaging Technology</i>	-	91.384	108.294	92.359	0.000	92.359	88.856	89.562	93.058	95.164	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project explores the technical feasibility of moderate to high power lasers, including beam control, for applications such as aircraft protection, force protection, and precision engagement from Air Force platforms. This project investigates the effects of laser weapons on a wide range of systems and components as well as producing, modifying, validating and applying Directed Energy (DE) and non-Directed Energy concept development and assessment tools to determine which technology solutions to pursue. This project conducts research supporting ground-based optical space situational awareness (SSA).

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: High Energy Laser Technologies and Directed Energy Assessments	60.251	82.619	66.145	0.000	66.145
Description: Develop and demonstrate High Energy Laser (HEL) device technologies for Air Force applications. Develop and demonstrate optical laser beam control technologies including atmospheric propagation and pointing and tracking. Perform laser system level modeling and simulation validated by laser effects and vulnerability testing. Develop tools and perform assessments which allow comparisons among (DE) concepts and tradeoffs between Directed Energy (DE) and non-Directed Energy solutions. Integrate optical beam control technologies with laser device technologies and demonstrate the combined technologies. Develop and use technologies to better understand the vulnerability of weapon systems to High Energy Lasers.					
FY 2019 Plans: Develop beam control technologies including aero-effects mitigation techniques. Power-scale monolithic fiber amplifiers using advanced fibers. Conduct effects testing to establish system requirements and validate models. Finish pod development and integration of low power laser subsystems for FY 2020 pod-mounted low power airborne laser demonstration. Begin integration of beam control into pod for Phase I low power laser system including ground support and aircraft interface. Begin fabrication of moderate power laser subsystem for use in Phase 2 aircraft self-protect 2021/2022 demonstration vs representative targets. Begin laboratory development of ultra-compact laser sub-system for future airborne applications. Transition the functionality of the Integrated Weapons Environment for Analysis engagement level model into the Advanced Framework for Simulation model for engagement and mission level analysis for internal and external users and utilize Advanced Framework for Simulation Advanced Framework for Simulation model as the weapons server in an advanced framework to support Air Force-wide modeling, simulation, and analysis. Continue to assess Directed Energy weapon and/or synergistic Directed Energy weapon/Kinetic Energy weapon capabilities to help users plan weapon					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>	Project (Number/Name) 624866 / <i>Lasers & Imaging Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>investments. Continue to model and characterize foreign high energy laser threats, and provide information to develop mitigation techniques to protect blue assets.</p> <p>FY 2020 Base Plans: Continue to develop beam control technologies including aero-effects mitigation techniques based on supersonic data from laboratory and flight tests. Continue to power scale monolithic fiber amplifiers using advanced fibers. Continue with effects testing to establish system requirements and validate models. Complete integration of beam control subsystems into pod for FY 2020 pod-mounted low power ground and airborne laser demonstration. Begin ground demonstration of Phase I low power laser podded system. Complete development of moderate power system into a pod for Phase 2 moderate power aircraft self-protect demonstration vs representative targets in FY 2021. Complete prototype module for fully packaged ultra-compact fiber amplifier laser. Continue to transition the functionality of the Integrated Weapons Environment for Analysis engagement level model into the Advanced Framework for Simulation model for engagement and mission level analysis for internal and external users and utilize the Advanced Framework for Simulation model as the weapons server in an advanced framework to support Air Force-wide modeling, simulation, and analysis (MS&A). Continue to assess directed energy weapon and/or synergistic directed energy weapon/kinetic energy weapon capabilities to help users plan weapon investments. Continue to model and characterize foreign high energy laser threats, and provide information to develop mitigation techniques to protect blue assets.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$16.474 million. Funding decreased due to re-scoping of Laser Subsystem Development activities.</p>					
<p>Title: Optical Space Situational Awareness and Satellite Vulnerability</p> <p>Description: Develop advanced, long-range, electro-optical technologies that enable ground-based optical Space Situational Awareness (SSA) and quantum-based optical communications. Develop and use technologies to understand the vulnerability of blue satellite systems and components to lasers. Operate the Starfire Optical Range (SOR) to conduct research meeting internal and customer requirements.</p> <p>FY 2019 Plans: Field the dynamic telescope subsystem that searches the geosynchronous satellite belt visible from the mid-Pacific multiple-times per night, enabling a periodic comprehensive census of dim objects in the geo-belt. Mature daylight detection of geosynchronous satellites thus allowing custody through daytime hours when</p>	31.133	25.675	26.214	0.000	26.214

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>	Project (Number/Name) 624866 / <i>Lasers & Imaging Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)

satellites cannot normally be detected by our ground-based optical systems. Mature component technologies for 24/7 real-time optical imaging of near-earth satellites enabling characterization on tactical timelines. Use Modelling and Simulation to investigate the susceptibility of satellite components to laser threats to inform practical designs for protection equipment and for tactically-rapid course-of-action decision-making enabling protection methods. Develop laser-enabled space situational awareness (SSA) techniques focused on full-dark imaging using laser illumination. Investigate laser-enabled options for both ranging to and imaging of geosynchronous satellites from apertures smaller than 3 meters. Develop long-range secure optical communications technologies leveraging quantum science for free space lasercom channels. Conduct engineering-model simulations of laser-enabled system capable of imaging objects in geosynchronous orbit from ground-based optical sensors. Demonstrate a machine-learning algorithm that can automatically predict several seconds ahead the optical aberrations caused by atmospheric turbulence and do so more accurately and rapidly than current "hard-wired" algorithms can. Maintain Starfire Optical Range (SOR) facility and experimental equipment in a mission-ready state.

FY 2020 Base Plans:

Continue fielding the dynamic telescope subsystem that searches the geosynchronous satellite belt visible from the mid-Pacific multiple-times per night, enabling a periodic comprehensive census of dim objects in the geo-belt. Continue to mature daylight detection of geosynchronous satellites thus allowing custody through daytime hours when satellites cannot normally be detected by our ground-based optical systems. Continue to mature component technologies for 24/7 real-time optical imaging of near-earth and geosynchronous objects enabling characterization on tactical timelines. Continue investigation through modeling and simulation the susceptibility of satellite components to laser threats to inform practical designs for protection equipment and for tactically-rapid course-of-action decision-making enabling protection methods. Continue development of laser-enabled space situational awareness (SSA) research focused on full-dark imaging using laser illumination. Investigate laser-enabled options for both ranging to and imaging of geosynchronous satellites from apertures smaller than 3 meters. Continue development of long-range secure optical communications technologies leveraging quantum science for free space lasercom channels. Continue project to apply machine-learning to automatically identify geosynchronous-orbit objects more accurately and rapidly than current "hard-wired" algorithms can. Continue to maintain Starfire Optical Range (SOR) facility and experimental equipment in a mission-ready state.

FY 2020 OCO Plans:

Not Applicable

FY 2019 to FY 2020 Increase/Decrease Statement:

FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>	Project (Number/Name) 624866 / <i>Lasers & Imaging Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 increased compared to FY 2019 by \$0.539 million. Justification for increase is described the plans above.					
Accomplishments/Planned Programs Subtotals	91.384	108.294	92.359	0.000	92.359

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>				Project (Number/Name) 624867 / <i>Advanced Weapons & Survivability Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624867: <i>Advanced Weapons & Survivability Technology</i>	-	30.226	33.506	32.020	0.000	32.020	35.837	37.903	39.388	40.270	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project explores the use of High Power Microwave (HPM) and other unconventional/innovative weapon concepts to support applications such as nonlethal counter-personnel and electronic warfare including disruption, degradation, and damage of electronic infrastructure on Air Force platforms. This research includes weapon technology that can provide covert effects and/or no collateral or human damage. The project also investigates the effects of potential adversary High Power Microwave weapons and how to mitigate those effects on US assets, as well as producing and applying Directed Energy (DE) and non-Directed Energy concept development and assessment tools to determine which technology solutions to pursue. This project includes but is not limited to high power microwaves, plasmas, particle beams and millimeter waves.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: High Power Microwave and Unconventional Weapon Technologies	12.642	12.231	11.541	0.000	11.541
Description: Investigate technologies for High Power Microwave and unconventional weapon components. Investigate High Power Microwave and other unconventional weapon concepts using innovative technologies. Investigate advanced technologies that support force protection tactical applications, including non-kinetic/non-lethal counter-electronics applications.					
FY 2019 Plans: Complete ultra-short pulsed laser atmospheric propagation studies in a density gradient. Complete effects studies on electronics based on the assessments from FY 2016 and FY 2017 to support a joint High Power Microwave program with the Navy. Design and develop High Power Microwave components for ground and aerial High Power Microwave demonstrators. Design and develop smaller, higher power, source technology for the joint Air Force-Navy High Power Microwave demonstration.					
FY 2020 Base Plans: Assess the military utility of an ultra-short pulsed laser system. Conduct effects testing on electronics based on the target classes for the joint high power microwave program with the Navy. Develop and test high power microwave components for ground and aerial high power microwave demonstrators. Develop and test smaller, higher power, source technology for the joint Air Force-Navy high power microwave demonstration.					
FY 2020 OCO Plans:					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>	Project (Number/Name) 624867 / <i>Advanced Weapons & Survivability Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Not Applicable					
<p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$0.690 million. Justification for the decrease is described in the plans above.</p>					
<p><i>Title:</i> High Power Microwave Effects and Mitigation Research</p> <p><i>Description:</i> Assess the effects/lethality of High Power Microwave technologies. Develop and apply sophisticated models to enhance the development of High Power Microwave and related technology. Develop tools and perform assessments which allow comparisons among Directed Energy concepts and tradeoffs between Directed Energy and non-Directed Energy solutions. Investigate technologies to counter the effects of High Power Microwaves.</p> <p><i>FY 2019 Plans:</i> Improve software applications that are hosted in the Directed Energy High Performance Computing Software Applications Institute for a broad spectrum directed energy sources. Develop end-to-end modeling and weapon utility assessments to incorporate High Power Microwave weapon technology into various platforms for multiple target prosecutions. Build synergistic weapon concept assessments that merge kinetic energy and non-kinetic energy weapon investments. Support the Modeling, Simulation, and Analysis tools that have been transitioned to the broader Modeling, Simulation, and Analysis community.</p> <p><i>FY 2020 Base Plans:</i> Assess the military utility of an ultra-short pulsed laser system. Conduct effects testing on electronics based on the target classes for the joint High Power Microwave (HPM) program with the Navy. Develop and test high power microwave components for ground and aerial High Power Microwave demonstrators. Develop and test smaller, higher power, source technology for the joint Air Force-Navy high power microwave (HPM) demonstration. Continue to support the Modeling, Simulation, and Analysis (MS&A) tools that have been transitioned to the broader Modeling, Simulation, and Analysis community.</p> <p><i>FY 2020 OCO Plans:</i> Not Applicable</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i></p>	17.584	21.275	20.479	0.000	20.479

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602605F / <i>Directed Energy Technology</i>	Project (Number/Name) 624867 / <i>Advanced Weapons & Survivability Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 decreased compared to FY 2019 by \$0.796 million. Justification for the decrease is described in plans above.					
Accomplishments/Planned Programs Subtotals	30.226	33.506	32.020	0.000	32.020

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not Applicable

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	191.724	185.276	181.562	0.000	181.562	184.766	191.106	177.037	180.741	Continuing	Continuing
625315: <i>C4I Dominance Technology</i>	-	43.214	32.338	99.855	0.000	99.855	100.696	105.352	88.899	90.761	Continuing	Continuing
625316: <i>Info Mgt and Computational Tech</i>	-	10.220	19.589	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29.809
625317: <i>Information Decision Making Tech</i>	-	35.024	16.719	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	51.743
625318: <i>Operational Awareness Tech</i>	-	27.214	22.338	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	49.552
625319: <i>Cyberspace Dominance Technology</i>	-	55.011	73.242	60.281	0.000	60.281	62.084	63.351	65.603	66.969	Continuing	Continuing
620MMS: <i>Research Site Support</i>	-	21.041	21.050	21.426	0.000	21.426	21.986	22.403	22.535	23.011	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops enterprise-centric information technology for the Air Force. Advances in enterprise-centric information technologies are required to increase warfighter readiness and effectiveness by providing the right information, at the right time, in the right format, anytime, anywhere in the world. The Connectivity and Protection Tech project provides the technologies for multi-level, secure, seamless networks; advanced communications processors; anti-jam and low probability of intercept techniques, as well as technologies that deter any adversary from attacking computer systems while allowing access to, presence on, manipulation of, and operational effects on adversary computer systems. This project also develops the technology base for the next generation of ultra-wide-bandwidth, multi-channeled, air- and space-based communications networks. The Information Management and Computational Tech project provides advances in information management and dissemination technologies to ensure the delivery of high-quality, timely, secure information to the warfighter, and develop technologies to produce both advanced on demand computational processing and computer architectures with greater capacity and sophistication for addressing dynamic mission objectives under constraints imposed by Air Force systems. The Information Decision Making Tech project develops the technology to support the commander and staff's ability to command all viable options to achieve desired effects across the full spectrum of operations. The Operational Awareness Tech project develops technologies that improve their capability to generate, process, manage, fuse, exploit, interpret, and disseminate timely and accurate information. The Research Site Support project provides the Rome Research Site infrastructure at Rome, New York and provides for the continued operations of all Rome Research Site properties, buildings, and services necessary for the research mission. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

In FY 2020, Project 625315 renamed from Connectivity and Protection Tech to C4I Dominance Technology.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>
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In FY 2020, Project 625316, Info Mgt and Computational Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

In FY 2020, Project 625317, Information Decision Making Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

In FY 2020, Project 625318, Operational Awareness Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0622041F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	167.818	162.420	173.761	0.000	173.761
Current President's Budget	191.724	185.276	181.562	0.000	181.562
Total Adjustments	23.906	22.856	7.801	0.000	7.801
• Congressional General Reductions	-0.090	-0.144			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	26.500	23.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.198	0.000			
• SBIR/STTR Transfer	-2.702	0.000			
• Other Adjustments	0.000	0.000	7.801	0.000	7.801

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>
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Congressional Add Details (\$ in Millions, and Includes General Reductions)	FY 2018	FY 2019
Project: 625315: C4I Dominance Technology Congressional Add: <i>Program Increase Line 13B</i>	12.819	0.000
Congressional Add Subtotals for Project: 625315	12.819	0.000
Project: 625316: Info Mgt and Computational Tech Congressional Add: <i>Program Increase - Quantum Computing CoE</i>	0.000	7.500
Congressional Add Subtotals for Project: 625316	0.000	7.500
Project: 625317: Information Decision Making Tech Congressional Add: <i>Program increase Line 13A</i> Congressional Add: <i>Program increase Line 13B</i>	4.930	0.000
Congressional Add Subtotals for Project: 625317	7.395	0.000
Project: 625318: Operational Awareness Tech Congressional Add: <i>Program increase - quantum computing</i>	5.917	0.000
Congressional Add Subtotals for Project: 625318	5.917	0.000
Project: 625319: Cyberspace Dominance Technology Congressional Add: <i>Program Increase - Cyber Testbed for Unidentified C-UAS</i> Congressional Add: <i>Program Increase Line 13A</i>	0.000	5.500
Congressional Add Subtotals for Project: 625319	0.000	15.500
Congressional Add Totals for all Projects	26.131	23.000

Change Summary Explanation

Increase in FY 2020 due to civilian pay repricing adjustment and realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625315 / <i>C4I Dominance Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To	Total
											Complete	Cost
625315: <i>C4I Dominance Technology</i>	-	43.214	32.338	99.855	0.000	99.855	100.696	105.352	88.899	90.761	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Air Force requires advanced technologies which support the Air Force five core missions and enable the Air Force to achieve Global Vigilance, Global Reach, and Global Power in support of national security objectives. The technologies developed under this project enable the National Defense Strategy and Air Force future operating concepts which require operational agility (the ability to rapidly generate—and shift among—multiple solutions for a given challenge), creating combinations of air, space, and cyberspace capabilities to achieve desired effects in the battlespace.

This project provides the technologies for secure, self-configuring, self-healing, seamless networks; advanced communications processors; anti-jam and low probability of intercept communications techniques; agile and dynamic policy-based network management capabilities; and modular, programmable, low-cost software radios. In addition, it develops both the technology base for ultra-wide bandwidth and multi-channeled communications networks (both air and space based) on and between platforms.

This project provides the technologies which enable the ability to globally share, discover, and access information across organizational, functional, and coalition boundaries and between and among domains, the timely delivery of information to tactical assets, the tailoring and prioritization of information based on mission needs and importance, and the scaling, robustness, and collaboration features required of the Air Force net-centric information management environment.

This project advances technologies enabling the effective execution of military objectives that will vastly improve the ability to support the commander and staff's ability to command all viable options to achieve desired effects across the full spectrum of operations (air, space, and cyberspace) at all levels of war (strategic, operational, and tactical) and during all phases of conflict. This project provides technologies for anticipatory decision support; course of action development, planning, scheduling, and assessment; and the real-time effective portrayal of complex data sets.

This project improves and automates the capability to generate, process, manage, fuse, exploit, interpret, and disseminate timely and accurate information. This project provides not only a network-centric, collaborative intelligence analysis capability that enables the fusion of multi-intelligence and sensor sources to provide timely situational awareness, understanding, and anticipation of the threats in the battlespace, but also the advanced, novel exploitation technologies needed to intercept, collect, locate, and process both covert and overt raw data from intelligence and sensor sources.

In FY 2020, Project 625315 renamed from Connectivity and Protection Tech to C4I Dominance Technology.

In FY 2020, Project 625316, Info Mgt and Computational Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625315 / <i>C4I Dominance Technology</i>
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In FY 2020, Project 625317, Information Decision Making Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

In FY 2020, Project 625318, Operational Awareness Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Advanced Connectivity Technologies</p> <p>Description: Develop improved, survivable, higher bandwidth communications, networking, and signal processing technologies to provide secure, adaptive, covert, anti-jam, and assured global battlespace connectivity tailored to anti-access and area-denial environments and contested operations.</p> <p>FY 2019 Plans: Continue the research and development of Aerial Layer Network Components and prototype technologies for robust, adaptive, and mission aware airborne networks. Advance the research and investigation of high frequency pathways (e.g. the V and W band of the electromagnetic spectrum) to support aerial and space-based beyond line of sight communications. Expand the research and development of dynamic map-to-mission for secure message exchange operations continuity and agile info management. Develop a waveform testbed and flight test a new multi-waveform radio. Conduct research and development to measure propagation at millimeter wave frequencies to validate previously developed models and enable future definition of military satellite communications systems. Complete autonomic network model and simulation. Complete low overhead network monitoring and management protocol. Continue ionospheric research, propagation modeling and simulation.</p> <p>FY 2020 Plans: Starting in FY 2020, this work is performed in the Assured Communications & Networks effort.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$32.338 million. Funding decreased due to realignment of advanced network and communication research under the Assured Communications & Networks effort.</p>	30.395	32.338	0.000
<p>Title: Assured Communications & Networks</p> <p>Description: Develop communications, networking, and signal processing technologies with improved survivability and capacity to provide secure, adaptive, covert, anti-jam, and assured global battlespace connectivity tailored to anti-access and area-denial environments and contested operations.</p> <p>FY 2019 Plans:</p>	0.000	0.000	23.680

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625315 / <i>C4I Dominance Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>For FY 2019 and prior years, this work is performed under the Advanced Connectivity Technologies effort.</p> <p>FY 2020 Plans: Continue the research and development of technologies for robust, adaptive, and mission aware airborne networks. Continue the investigation of high frequency pathways (for example, the V and W band of the electromagnetic spectrum) to support aerial and space-based beyond line of sight communications. Continue the research and development of dynamic map-to-mission for secure message exchange operations continuity and agile info management. Continue development of a waveform testbed and flight test a new multi-waveform radio. Continue research and development to measure propagation at millimeter wave frequencies to validate previously developed models and enable future definition of military satellite communications systems. Continue ionospheric research, propagation modeling and simulation.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$23.680 million. Funding increased due to realignment of advanced network, connectivity, and communications research from Advanced Connectivity Technologies effort.</p>			
<p>Title: Data to Decisions</p> <p>Description: Investigate and develop technologies for decision quality information dissemination services via publish, subscribe, and query across the Global Information Grid to enterprise and tactical assets and coalition partners.</p> <p>FY 2019 Plans: For FY 2019 and prior years, this work is performed under both Exploitation Technologies and Multi-Source Fusion Technologies efforts within Project 625318, Operational Awareness Tech.</p> <p>FY 2020 Plans: Continue the research and development of data analytics and strategic indications and warnings technologies (including large data alignment, indexing and search on textual data, large-scale and disparate data sources, both structured and unstructured data, and employment of various ontologies and machine learning techniques). Continue to advance research and development for cloud-based data and information sharing environment for optimized processing and automated association capability. Continue to focus signals intelligence characterization on audio and other electronic signals. Continue research and development in exploitation technologies using audio processing for language modeling and deep learning techniques. Continue research on enhanced emitter feature extraction capabilities and development of automated electronics intelligence analysis toolsets.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$13.272 million. Funding increased due to realignment of advanced network-centric multi-source fusion, tracking and identification, situational awareness, analysis and understanding, threat anticipation, spectral</p>	0.000	0.000	13.272

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625315 / <i>C4I Dominance Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
detection and geolocation, signal recognition and analysis, and associated data tagging, tracking, and tracing research from Project 625318, Operational Awareness Tech.				
<p>Title: Multi-Domain Command & Control (MDC2)</p> <p>Description: Develop advanced monitoring, planning, and assessment technologies enabling aerospace commanders to develop effects-based campaigns. Investigate, analyze, and develop technologies for planning, execution, and automatic rapid reconfiguration of distributed intelligent and integrated command and control information systems to achieve the commander's intent throughout varying crisis levels.</p> <p>FY 2019 Plans: For FY 2019 and prior years, this work is performed under Command and Control System Technologies effort within Project 625317, Information Decision Making Tech.</p> <p>FY 2020 Plans: Continue to leverage prior efforts in developing plan assessment services and conduct quantitative evaluations of cyber assets to cyber operators, enabling them to present viable cyber options to commanders for multi-domain (air, space, cyberspace, land, sea, undersea) integrated plans. Continue the development of command and control system technologies in the area of multi-domain command and control. Continue research for applying machine learning techniques to enhance and optimize space operations.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$17.954 million. Funding increased due to realignment of anticipatory decision support, course of action development, planning, scheduling, assessment, and real-time complex data-set portrayal research from Project 625317, Information Decision Making Tech.</p>		0.000	0.000	17.954
<p>Title: Artificial Intelligence/Autonomy/Machine Learning</p> <p>Description: Perform research and development (R&D) to harness the speed and scale of computers and machines to address problems of complexity.</p> <p>FY 2019 Plans: For FY 2019 and prior years, this work is performed under Campaign Planning Technologies effort within Project 625317, Information Decision Making Tech.</p> <p>FY 2020 Plans:</p>		0.000	0.000	14.808

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625315 / <i>C4I Dominance Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Continue to research combat planning and tactical assessment software services. Continue research for identifying and implementing state-of-the-art learning models. Develop algorithms for data-efficient leaning and integrate with a machine learning framework.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$14.808 million. Funding increased due to realignment of anticipatory decision support, course of action development, planning, scheduling, assessment, and real-time complex data-set portrayal research from Project 625317, Information Decision Making Tech.</p>				
<p>Title: Nuclear C3 Modernization</p> <p>Description: Perform research and development (R&D) to advance existing nuclear capable forces to ensure command, control, and connectivity for the President without constraints.</p> <p>FY 2019 Plans: For FY 2019 and prior years, this work is performed under Advanced Connectivity Technologies effort.</p> <p>FY 2020 Plans: Continue high-frequency (HF) mesh networking algorithm development, further very low frequency (VLF) software-defined radio (SDR) development. Continue to enhance/modernize propagation tools and the High Frequency Laboratory, and, will initiate trans-auroral and trans-equatorial long haul communication.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$3.893 million. Funding increased due to realignment of advanced nuclear network, connectivity, and communications research from the Advanced Connectivity Technologies effort.</p>		0.000	0.000	3.893
<p>Title: Quantum Information Science</p> <p>Description: Perform research and development (R&D) that will utilize quantum physics for the storage, transmission, manipulation, computing, or measurement of information in ways that offer advantages to classical capabilities.</p> <p>FY 2019 Plans: For FY 2019 and prior years, this work is performed under Advanced Connectivity Technologies effort.</p> <p>FY 2020 Plans: Continue research and development in the area of supreme and quantum computing information sciences to establish the memory-based network nodes, to further evolve and adapt the photon-based interconnects, and to develop an integration scheme to interface a quantum network. Continue testing the ability to teleport quantum information between network nodes, and to</p>		0.000	0.000	6.581

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625315 / <i>C4I Dominance Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
establish two-way quantum communication between two memory nodes. Conduct an analysis of conventional/quantum channel interface for long-distance communication. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$6.581 million. Funding increased due to realignment of all quantum network, connectivity, and communications research from Advanced Connectivity Technologies effort.				
Title: Future AF Capabilities Applied Research Description: Investigate, design, and develop science and technologies supporting future Air Force capabilities to provide compelling advantage to the warfighter. To the greatest extent practical, research efforts will utilize modeling and simulation and cross-discipline systems integration (For example: air and space vehicles, avionics, propulsion, materials, human performance, cybersecurity, command, control, communications, computer and intelligence, sensors, electronic warfare, and conventional/unconventional weapons). The National Defense Strategy and Air Force Science and Technology 2030 Strategy will inform investments over the FYDP. FY 2019 Plans: In FY 2019, this work is performed under multiple projects and efforts within the following Air Force Science and Technology Programs: 0602102F, Materials; 0602201F, Aerospace Vehicle Technologies; 0602202F, Human Effectiveness Applied Research; 0602203F, Aerospace Propulsion; 0602204F, Aerospace Sensors; 1206601F, Space Technology; 0602602F, Conventional Munitions; 0602605F, Directed Energy Technology; and 0602788F, Dominant Information Science and Methods. FY 2020 Plans: Continue to investigate and mature science and technology that enables future warfighting concepts to provide leap-ahead capabilities. The National Defense Strategy and Air Force Science and Technology 2030 Strategy focus this science and technology toward, but not limited to, the following capabilities: 1) global persistent awareness; 2) resilient information sharing; 3) rapid, effective decision-making; 4) complexity, unpredictability, and mass; and 5) speed and reach of disruption and lethality. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$19.667 million. Funding increased due to the realignment and consolidation of Air Force Applied Research Science and Technology funding for Future Air Force Capabilities Applied Research efforts.		0.000	0.000	19.667
Accomplishments/Planned Programs Subtotals		30.395	32.338	99.855
		FY 2018	FY 2019	
Congressional Add: Program Increase Line 13B		12.819	0.000	

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625315 / <i>C4I Dominance Technology</i>
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	FY 2018	FY 2019
FY 2018 Accomplishments: Conducted Congressionally directed efforts.		
FY 2019 Plans: Not applicable		
Congressional Adds Subtotals	12.819	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>				Project (Number/Name) 625316 / <i>Info Mgt and Computational Tech</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625316: <i>Info Mgt and Computational Tech</i>	-	10.220	19.589	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29.809

A. Mission Description and Budget Item Justification

The Air Force requires the capability to maximize the value, sharing, management, and use of its information and information assets in achieving its mission objectives as the importance of information grows in the current net-centric environment. Technology development in this project must be capable of taking advantage of future net-centric environments including new structured and ad hoc processes in response to rapidly changing warfare challenges. Advances in robust information management focus on quality of service and flow of information within the enterprise, information transformation and brokering, secure information sharing across and among domains, and collaboration of workflow within the enterprise. Technologies addressed in this project include the ability to globally share, discover, and access information across organizational, functional, and coalition boundaries and between and among domains, the timely delivery of information to tactical assets, the tailoring and prioritization of information based on mission needs and importance, and the scaling, robustness, and collaboration features required of the Air Force net-centric information management environment.

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. In order to enable multi-domain operations, this project will begin to shape future research and development to focus on the capability to maximize the value, sharing, management, and use of information and information assets in support of multi-domain command and control.

In FY 2020, Project 625316, Info Mgt and Computational Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Dissemination Technologies	10.220	12.089	0.000
Description: Investigate and develop technologies for decision quality information dissemination services via publish, subscribe, and query across the Global Information Grid to enterprise and tactical assets and coalition partners.			
FY 2019 Plans: Continue research that will enable multiple echelons of a battlefield command to adapt operations to changing situations and dynamically select from the best set of mission options. Advance the research of highly scalable mission oriented middleware that semantically characterizes and contextualizes information to automatically identify and deliver mission relevant information to			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625316 / <i>Info Mgt and Computational Tech</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
consumers in federated environments. Focus research in the area of Multi-Domain Command and Control. Continue development of integrated and field tested tactical-to-enterprise information management services.			
<i>FY 2020 Plans:</i> Starting in FY 2020, the work is performed under the Assured Communications & Networks effort within Project 625315, C4I Dominance Technology.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$12.089 million. Funding decrease due to realignment of advanced network, information management, and communications research under Project 625315, C4I Dominance Technology.			
Accomplishments/Planned Programs Subtotals	10.220	12.089	0.000

	FY 2018	FY 2019
<i>Congressional Add:</i> Program Increase - Quantum Computing CoE	0.000	7.500
<i>FY 2018 Accomplishments:</i> Not Applicable		
<i>FY 2019 Plans:</i> Conduct Congressionally directed efforts.		
Congressional Adds Subtotals	0.000	7.500

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>				Project (Number/Name) 625317 / <i>Information Decision Making Tech</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625317: <i>Information Decision Making Tech</i>	-	35.024	16.719	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	51.743

A. Mission Description and Budget Item Justification

The Air Force requires advances in technologies enabling the effective execution of military objectives that will vastly improve the ability to support the commander and staff's ability to command all viable options to achieve desired effects across the full spectrum of operations (air, space, and cyberspace) at all levels of war (strategic, operational, and tactical) and during all phases of conflict. Technology development in this project includes anticipatory decision support; course of action development, planning, scheduling, and assessment; and the real-time effective portrayal of complex data sets.

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. In order to enable multi-domain operations, this project will begin to shape future research and development to focus on the capability to maximize the value, sharing, management, and use of information and information assets in support of multi-domain command and control.

In FY 2020, Project 625317, Information Decision Making Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Campaign Planning Technologies	5.268	9.888	0.000
Description: Develop advanced monitoring, planning, and assessment technologies enabling aerospace commanders to develop effects-based campaigns.			
FY 2019 Plans: Continue to research combat planning and tactical assessment software services and increase applied research in the area of multi-domain command and control for campaign planning and battlefield management. Continue research for identifying and implementing state-of-the-art learning models. Develop algorithms for data-efficient learning and integrate with a machine learning framework. Develop algorithms that will dynamically adapt to varying situations based on situational awareness.			
FY 2020 Plans: Starting in FY 2020, the work is performed under the Artificial Intelligence/Autonomy/Machine Learning effort, Project 625315 C4I Dominance Technology.			
FY 2019 to FY 2020 Increase/Decrease Statement:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625317 / <i>Information Decision Making Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 decreased compared to FY 2019 by \$9.888 million. Funding decreased due to realignment of advanced monitoring, planning, and assessment research under Project 625315, C4I Dominance Technology.			
<p>Title: Command and Control System Technologies</p> <p>Description: Investigate, analyze, and develop technologies for planning, execution, and automatic rapid reconfiguration of distributed intelligent and integrated command and control information systems to achieve the commander's intent throughout varying crisis levels.</p> <p>FY 2019 Plans: Leverage prior efforts in developing plan assessment services and conduct quantitative evaluations of cyber assets to cyber operators, enabling them to present viable cyber options to commanders for multi-domain (air, space, cyberspace, land, sea, undersea) integrated plans. Initiate research and development of command and control system technologies in the area of multi-domain command and control. Initiate research for applying machine learning techniques to enhance and optimize space operations.</p> <p>FY 2020 Plans: Starting in FY 2020, the work is performed under the Multi-Domain Command and Control effort Project 625315, C4I Dominance Technology.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$6.831 million. Funding decreased due to realignment of all distributed, intelligent, and integrated command and control information system research under Project 625315, C4I Dominance Technology.</p>	22.361	6.831	0.000
Accomplishments/Planned Programs Subtotals	27.629	16.719	0.000

	FY 2018	FY 2019
<p>Congressional Add: Program increase Line 13A</p> <p>FY 2018 Accomplishments: Conducted Congressionally directed efforts.</p> <p>FY 2019 Plans: Not Applicable</p>	4.930	0.000
<p>Congressional Add: Program increase Line 13B</p> <p>FY 2018 Accomplishments: Conducted Congressionally directed efforts.</p> <p>FY 2019 Plans: Not Applicable</p>	2.465	0.000
Congressional Adds Subtotals	7.395	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625317 / <i>Information Decision Making Tech</i>

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>				Project (Number/Name) 625318 / <i>Operational Awareness Tech</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625318: <i>Operational Awareness Tech</i>	-	27.214	22.338	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	49.552

A. Mission Description and Budget Item Justification

The Air Force requires technologies that improve and automate the capability to generate, process, manage, fuse, exploit, interpret, and disseminate timely and accurate information. This project provides not only a network-centric, collaborative intelligence analysis capability that enables the fusion of multi-intelligence and sensor sources to provide timely situational awareness, understanding, and anticipation of the threats in the battlespace, but also the advanced, novel exploitation technologies needed to intercept, collect, locate, and process both covert and overt raw data from intelligence and sensor sources. It leads the research, discovery, and development of technology that enables the fusion of multi-intelligence sources to provide accurate object tracking and identification, situational awareness, understanding, and anticipation of the threats in the battlespace (air, ground, space, and cyber). It also leads in the development of advanced exploitation technologies to maximize the intelligence gained from our adversaries in the areas of spectral detection and geolocation, signal recognition and analysis, and the data tagging, tracking, and tracing via the insertion of secure, imperceptible signal embedding for future fusion and understanding of the information.

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. In order to enable multi-domain operations, the Air Force requires dynamic and elastic intelligence, surveillance, and reconnaissance forces and capabilities to provide actionable intelligence to commanders and to increase understanding of the environment and an adversary's capabilities and intentions.

In FY 2020, Project 625318, Operational Awareness Tech efforts will be transferred to Project 625315, C4I Dominance Technology, in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Multi-Source Fusion Technologies	11.782	10.117	0.000
Description: Develop higher-level fusion and the enabling text information/knowledge base technologies to achieve situational awareness and understanding at all command levels for dynamic planning, assessment, and execution processes.			
FY 2019 Plans: Continue the research and development of data analytics and strategic indications and warnings technologies (including large data alignment, indexing and search on textual data, large-scale and disparate data sources, both structured and unstructured data, and employment of various ontologies and machine learning techniques). Advance research and development for cloud-based data and information sharing environment for optimized processing and automated association capability.			
FY 2020 Plans:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625318 / <i>Operational Awareness Tech</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
Starting in FY 2020, the work is performed under the Data to Decisions effort Project 625315, C4I Dominance Technology. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$10.117 million. Funding decreased due to realignment of advanced network-centric multi-source fusion, tracking and identification, situational awareness, analysis and understanding, threat anticipation, spectral detection and geolocation, signal recognition and analysis, and associated data tagging, tracking, and tracing research under Project 625315, C4I Dominance Technology.				
Title: Exploitation Technologies Description: Develop digital information exploitation technologies for electronic communications and special signals intelligence, imagery, and measurement signatures to increase accuracy, correlation, and timeliness of the information. FY 2019 Plans: Focus signals intelligence characterization on audio and other electronic signals. Initiate research and development in exploitation technologies using audio processing for language modeling and deep learning techniques. Continue research on enhanced emitter feature extraction capabilities and development of automated electronics intelligence analysis toolsets. FY 2020 Plans: Starting in FY 2020, the work is performed under the Data to Decisions effort Project 625315, C4I Dominance Technology. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$10.970 million. Funding decreased due to realignment of advanced network-centric multi-source fusion, tracking and identification, situational awareness, analysis and understanding, threat anticipation, spectral detection and geolocation, signal recognition and analysis, and associated data tagging, tracking, and tracing research under Project 625315, C4I Dominance Technology.		8.269	10.970	0.000
Title: Next Generation Command Technologies Description: Develop modeling and simulation technologies for the next generation of planning, assessment, and execution environments. FY 2019 Plans: Continue research and development of capabilities to support situational awareness. Conduct extended user evaluations at designated operational sites to advance applied research for full spectrum targeting semantic capabilities and provide a cross-organization workflow. FY 2020 Plans:		1.246	1.251	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625318 / <i>Operational Awareness Tech</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Starting in FY 2020, the work will be performed under the Multi-Domain Command & Control effort Project 625315, C4I Dominance Technology.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$1.251 million. Funding decreased due to realignment of advanced network-centric tracking and identification, situational awareness, analysis and understanding, and threat anticipation research under Project 625315, C4I Dominance Technology.			
Accomplishments/Planned Programs Subtotals	21.297	22.338	0.000

	FY 2018	FY 2019
<i>Congressional Add:</i> Program increase - quantum computing	5.917	0.000
<i>FY 2018 Accomplishments:</i> Conducted Congressionally directed efforts.		
<i>FY 2019 Plans:</i> Not Applicable		
Congressional Adds Subtotals	5.917	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>				Project (Number/Name) 625319 / <i>Cyberspace Dominance Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625319: <i>Cyberspace Dominance Technology</i>	-	55.011	73.242	60.281	0.000	60.281	62.084	63.351	65.603	66.969	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Air Force requires technologies to deliver a full range of options in cyberspace on par with air and space dominance in each of the areas of cyber-attack, cyber defense, and cyber support to achieve the strategic capability of cyber dominance. The Air Force requires the development of superior, intelligent, on-demand computing to enable information superiority to include advances in secure information sharing across domains and boundaries as well as technologies that successfully deter any adversary from attacking computer systems anytime, anywhere by ensuring the Air Force's ability to: access, maintain presence on, and deliver effects to adversary systems; detect, defend, and respond to attacks on friendly computer systems and provide forensic analysis concerning those attack attempts; and provide cyber situational awareness to Air Force Commanders. In addition, the Air Force requires technology development that produces computing architectures with greater capacity and sophistication for addressing constrained, dynamic mission objectives; "game-changing" computing power to the warfighter, disruptive computing power at the tactical edge and for federated grid services; and interactive and real-time computing improving the usability of high-performance computing to the Air Force. It includes technologies in computational sciences and engineering, computer architectures and software intensive systems.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Cyber Defense Technologies	17.060	18.768	20.531
Description: Develop cyber defense and supporting technologies to detect, defend, and respond to attacks on computer systems as well as provide forensic concerning attacks.			
FY 2019 Plans: Continue research in the area of autonomous integrated cyber operations. Initiate applied research in the area of biologically resilient cyber technologies, mission-specific blockchain capabilities, and the alignment of cyber resilient services and dynamic management tailored towards unmanned aerial systems.			
FY 2020 Plans: Continue research in the area of autonomous integrated cyber operations. Continue applied research in the area of biologically resilient cyber technologies. Continue research into mission-specific block-chain capabilities, and the alignment of cyber resilient services and dynamic management tailored towards unmanned aerial systems.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.763 million. Funding increased due to added emphasis on blockchain research as a method to secure cyber transactions.			
Title: Cyber Offense Technologies	6.079	10.751	17.037

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019	
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625319 / <i>Cyberspace Dominance Technology</i>	
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019
<p>Description: Develop offensive cyber operations technologies to access, maintain presence on, and deliver effects to adversary systems.</p> <p>FY 2019 Plans: Continue to conduct research and development of new, leading-edge technologies that are game changing and employ dominant power for cyber offensive operations. Increase activity in capabilities for multi-function, non-kinetic cyber effects against adversarial systems. Demonstrate ground-based and airborne delivery of disrupt, deny, degrade, destroy, or deceive effects that are both cyber and physical/kinetic.</p> <p>FY 2020 Plans: Advance research and development of new, leading-edge technologies that are game changing and employ dominant power for cyber offensive operations. Continue increased activity in capabilities for multi-function, non-kinetic cyber effects against adversarial systems. Continue to demonstrate ground-based and airborne delivery of disrupt, deny, degrade, destroy, or deceive effects that are both cyber and physical/kinetic.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$6.286 million. Funding increased due to an emphasis on disruption, denial, degradation, destruction, and deception through airborne cyber effects.</p>			
<p>Title: Advanced Architectural Technologies</p> <p>Description: Develop the architectural mechanisms that form the basis for predictable software and high assurance systems.</p> <p>FY 2019 Plans: Continue research and validation of a cyber hardened (robust, secure) processor for embedded weapon systems. Continue applied research to create trusted and resilient embedded systems that are capable of identifying, localizing, and automatically repairing previously unknown and/or unintended vulnerabilities. Continue research and development of the neuromorphic processor and validate capabilities for dynamic learning on mobile and power-constrained platforms. Initiate development of software using evolutionary approaches to make embedded systems tolerant to unexpected and unforeseen situations.</p> <p>FY 2020 Plans: Sustain research and validation of a cyber hardened (robust, secure) processor for embedded weapon systems. Maintain applied research to create trusted and resilient embedded systems that are capable of identifying, localizing, and automatically repairing previously unknown and/or unintended vulnerabilities. Continue development of software using evolutionary approaches to make embedded systems tolerant to unexpected and unforeseen situations.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>		12.165	10.105
		7.689	

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625319 / <i>Cyberspace Dominance Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
FY 2020 decreased compared to FY 2019 by \$2.416 million. Funding decreased due to realignment of all neuromorphic processing research under this Project within effort, Processing Technologies.				
<p>Title: Processing Technologies</p> <p>Description: Develop automatic and dynamically reconfigurable, scalable, affordable distributed peta-flop processing technologies for real-time global information systems.</p> <p>FY 2019 Plans: Continue to research the application of novel neuromorphic systems for robust machine learning. Continue research and development in the area of supreme and quantum computing information sciences to establish the memory-based network nodes, to further evolve and adapt the photon-based interconnects, and to develop an integration scheme to interface a quantum network. Test the ability to teleport quantum information between network nodes, and to establish two-way quantum communication between two memory nodes. Conduct an analysis of conventional/quantum channel interface for long-distance communication.</p> <p>FY 2020 Plans: Extend research the application of novel neuromorphic systems for robust machine learning. Advance research and development of the neuromorphic processor and validate capabilities for dynamic learning on mobile and power-constrained platforms.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$4.223 million. Funding decreased due to realignment of all quantum information science research under Project 625315, C4I Dominance Technology.</p>		6.938	8.938	4.715
<p>Title: Survivability Technologies</p> <p>Description: Develop methods and technologies for controlled operation of information systems during attacks and fault conditions, minimizing vulnerabilities of cyber attacks, and guaranteeing the accuracy and correctness of data and codes.</p> <p>FY 2019 Plans: Continue to research concepts and capabilities for cyber survivability techniques and algorithms for counter-unmanned aerial systems. Design and develop a counter-unmanned aerial systems open architecture to enable interoperability. Continue to evolve autonomous machine learning functions. Validate and demonstrate automated workflows into defensive cyber operations systems.</p> <p>FY 2020 Plans: Maintain research concepts and capabilities for cyber survivability techniques and algorithms for counter-unmanned aerial systems. Sustain development of a counter-unmanned aerial systems open architecture to enable interoperability. Extend</p>		3.599	2.072	3.011

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625319 / <i>Cyberspace Dominance Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
evolution of autonomous machine learning functions. Pursue validation and demonstration of automated workflows into defensive cyber operations systems. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.939 million. Justification for the decrease is described in the plans above.				
Title: Cross-Domain Technologies Description: Develop secure cross-domain discovery services for access to services outside the existing domain. Develop the tools to allow collaboration of workflows required by the Air Force net-centric information management system. FY 2019 Plans: Continue research and development in cross-domain solution technologies by developing content filtering, with an emphasis on improving support for rapid inclusion of new data types with minimal requirements for lengthy data type threat assessments and minimal custom coding. Continue research and development for machine to machine interfaces. Develop cross-domain solution command and control capabilities to manage cross-domain solution risk based upon changes in mission and threat. FY 2020 Plans: Advance research and development in for cross-domain solution technologies by developing content filtering, with an emphasis on improving support for rapid inclusion of new data types with minimal requirements for lengthy data type threat assessments and minimal custom coding. Sustain research and development for machine to machine interfaces. Extend development of cross-domain solution command and control capabilities to manage cross-domain solution risks based upon changes in mission and threat for diversified platforms via hardware abstraction, containerization/separation of the operation system (mobile, desktop, server). FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.518 million. Justification for the decrease is described in the plans above.		3.663	6.462	5.944
Title: Cyber Technologies for Spectrum Warfare Description: Develop technologies combining electronic warfare, signals intelligence, communications, and cyber technologies that provide synergistic access, exploitation and effects across air and cyber domains in congested and contested environments. FY 2019 Plans: Continue development of active and passive methods to locate, acquire, and process data and signals of interest. Advance research in systems to perform blind data discovery associated with the Internet of Things. Identify items of interest associated with the Internet of Things. FY 2020 Plans:		5.507	0.646	1.354

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 625319 / <i>Cyberspace Dominance Technology</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
Continue to advance research in systems to perform blind data discovery associated with the Internet of Things. Pursue identification of items of interest associated with the Internet of Things. Initiate research for specific items of interest within the Internet of Things.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.708 million. Justification for the increase is described in the plans above.				
Accomplishments/Planned Programs Subtotals		55.011	57.742	60.281
		FY 2018	FY 2019	
Congressional Add: Program Increase - Cyber Testbed for Unidentified C-UAS		0.000	5.500	
FY 2018 Accomplishments: Not Applicable				
FY 2019 Plans: Conduct Congressionally directed efforts.				
Congressional Add: Program Increase Line 13A		0.000	10.000	
FY 2018 Accomplishments: Not Applicable				
FY 2019 Plans: Conduct Congressionally directed efforts.				
Congressional Adds Subtotals		0.000	15.500	
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				
D. Acquisition Strategy				
N/A				
E. Performance Metrics				
Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>				Project (Number/Name) 62OMMS / <i>Research Site Support</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
62OMMS: <i>Research Site Support</i>	-	21.041	21.050	21.426	0.000	21.426	21.986	22.403	22.535	23.011	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Air Force Research Laboratory Information Directorate leads the discovery, development and implementation of information science and technology to drive transformation within the Air Force and across the Department of Defense. The focus of the work is to provide the warfighter with the required technology-based capabilities to defend the Nation by unleashing the power of innovative information science and technology to anticipate, find, fix, track, target, engage, and assess anything, anytime, anywhere. Since the site is a single-purpose location which is not located on a military installation, the Information Directorate has unique requirements for supporting its science and technology mission. As the host unit, the directorate is responsible to provide the Rome Research Site infrastructure at Rome, New York and provide for the continued operations of all Rome Research Site properties, buildings, and services necessary for the research mission. Operations include: logistics and communication services, utilities, maintenance of facilities and structures, safety and security of the workforce and visiting researchers, and ensures compliance with the laws, regulations, and directives that pertain to site operations. These services are host unit responsibilities and are necessary to provide a safe and effective environment for the Research Site's workforce and mission.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Rome Research Infrastructure	21.041	21.050	21.426
Description: Provide the necessary services and support including, but not limited to: fire inspections, refuse collection, water, electricity, steam, heat, custodial, and grounds maintenance services to the Research Site. Provide the necessary support for the maintenance and repair of Research Site facilities (buildings and other structures), vehicle and equipment lease and security/safety inspections and services as necessary for compliance and safety/security of personnel and research assets. Provide the Research Site with long haul communications (using the Government Services Administration set of Networx contracts for Continental United States), trunk connectivity and wireless communications.			
FY 2019 Plans: Continue to provide civilian payroll and non-pay costs for installation operations in support of the Rome Research Site property and all onsite personnel. Continue to provide facilities, facility operations, facility sustainment, support equipment, contracts, and associated costs to plan, manage and execute the following functions: fire prevention, disaster preparedness, plant operation and purchase of commodity, refuse collection, pavement clearance of snow and ice, grounds maintenance including landscaping, real property special inspections, pest control, and custodial services. Continue to provide Real Property Management and Engineering Services, including: (1) Facility Management and Administration and (2) Installation Engineering Services. Facility Management includes public works management costs, contract management, material procurement, facility data management, furnishings management costs, and real estate management. Installation Engineering Services includes annual inspection of facilities, master planning, overhead of planning and design, overhead of construction management, and non Site Recovery			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 0602788F / <i>Dominant Information Sciences and Methods</i>	Project (Number/Name) 62OMMS / <i>Research Site Support</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Management service calls. Continue to provide basic installation communication services, including long haul trunk and telecommunications services. Continue to provide site vehicle lease under the Government Services Administration for logistics, security, and mission support.</p> <p><i>FY 2020 Plans:</i> Continue to provide civilian payroll and non-pay costs for installation operations in support of the Rome Research Site property and all onsite personnel. Continue to provide facilities, facility operations, facility sustainment, support equipment, contracts, and associated costs to plan, manage and execute the following functions: fire prevention, disaster preparedness, plant operation and purchase of commodity, refuse collection, pavement clearance of snow and ice, grounds maintenance including landscaping, real property special inspections, pest control, and custodial services. Continue to provide Real Property Management and Engineering Services, including: (1) Facility Management and Administration and (2) Installation Engineering Services. Facility Management includes public works management costs, contract management, material procurement, facility data management, furnishings management costs, and real estate management. Installation Engineering Services includes annual inspection of facilities, master planning, overhead of planning and design, overhead of construction management, and non Site Recovery Management service calls. Continue to provide basic installation communication services, including long haul trunk and telecommunications services. Continue to provide site vehicle lease for logistics, security, and mission support under the Government Services Administration.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$0.376 million. Justification for the decrease is described in the plans above.</p>				
Accomplishments/Planned Programs Subtotals		21.041	21.050	21.426
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				
D. Acquisition Strategy				
N/A				
E. Performance Metrics				
Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.				

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602890F / <i>High Energy Laser Research</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	40.156	43.192	44.221	0.000	44.221	45.103	46.019	46.948	47.887	Continuing	Continuing
625096: <i>High Energy Laser Research</i>	-	40.156	43.192	44.221	0.000	44.221	45.103	46.019	46.948	47.887	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program funds Department of Defense Directed Energy applied research through the Joint Directed Energy Transition Office. This program is part of an overall Department of Defense Directed Energy Science and Technology program. Directed Energy weapon systems have many potential advantages including speed of-light delivery, precision target engagement, significant magazine depth, low-cost per kill, and reduced logistics requirements. Directed Energy Weapon Systems have the potential to perform a wide variety of military missions including high value asset and base protection, precision strike and platform self-protection versus a wide variety of missile, rocket, artillery, mortar and air platforms. Efforts under this program are generally chosen for their potential to have an impact on multiple Directed Energy Weapon systems and multiple Service missions while complementing Service/Agency efforts that are directed at specific Service needs. A broad range of technologies are addressed in key areas such as laser sources, microwave sources, laser beam control, antennas, waveguides, modeling and simulation, and lethality mechanisms. This program supports the Senior Official as required. Efforts in this program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research	R-1 Program Element (Number/Name) PE 0602890F I High Energy Laser Research
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	43.049	43.359	44.221	0.000	44.221
Current President's Budget	40.156	43.192	44.221	0.000	44.221
Total Adjustments	-2.893	-0.167	0.000	0.000	0.000
• Congressional General Reductions	-0.104	-0.167			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.497	0.000			
• Other Adjustments	-1.292	0.000	0.000	0.000	0.000

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

C. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Directed Energy Technologies	7.136	7.663	7.750	0.000	7.750
Description: Mature technologies that will provide system level performance commensurate with fieldable directed energy devices.					
In FY 2019, this effort was named Solid State Laser Technologies. Name changed to reflect the direction in the 2017 National Defense Authorization Act.					
FY 2019 Plans: Develop high reliability, lower cost, efficient and high temperature diode pump sources. Scale alternate laser wavelengths to additional militarily relevant uses and power levels. Investigate high power fiber technologies. Reduce technical risk in solid state lasers for inclusion in future laser weapon systems. Analyze trade space to understand performance, fielding, robustness and integration issues for military platforms. Investigate, analyze trade space, and reduce technical risk for high power microwave devices.					
FY 2020 Base Plans: Continue to develop high reliability, lower cost, efficient and high temperature diode pump sources. Continue to scale alternate laser wavelengths to additional militarily relevant uses and power levels. Investigate high power					

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602890F / <i>High Energy Laser Research</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>fiber technologies. Continue to reduce technical risk in solid state lasers for inclusion in future laser weapon systems. Continue trade space analysis to understand performance, fielding, robustness and integration issues for military platforms. Continue to investigate, analyze trade space, and reduce technical risk for high power microwave devices.</p> <p>FY 2020 OCO Plans: Not Applicable.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.087 million. Justification for the decrease is described in the plans above.</p>					
<p>Title: Advanced Directed Energy Technologies</p> <p>Description: Investigate new technologies that have revolutionary potential for high energy lasers and high power microwaves.</p> <p>In FY 2019, this effort was named Advanced Laser Technologies. Name changed to reflect the direction in the 2017 National Defense Authorization Act.</p> <p>FY 2019 Plans: Explore advanced concepts for directed energy technologies that will improve efficiency and decrease mass and volume for future weapon systems. Evaluate materials for directed energy applications. Improve understanding of short-pulse laser technologies to include material interaction and propagation. Scale electrically-pumped alkali vapor lasers to higher kilowatt class power levels. Characterize and understand the physics of high energy laser atmospheric propagation in adverse environmental conditions such as fog, rain, smoke and dust. Evaluate and test Avoidance and Air Space De-confliction systems on directed energy test ranges. Collaborate with the international directed energy community. Validate predictive models through analysis of atmospheric propagation data and measurements.</p> <p>FY 2020 Base Plans: Continue to explore advanced concepts for directed energy technologies that will improve efficiency and decrease mass and volume for future weapon systems. Continue to evaluate materials for directed energy applications. Continue to improve understanding of short-pulse laser technologies to include material interaction and propagation. Continue to scale electrically-pumped alkali vapor lasers to higher kilowatt class power levels. Continue to characterize and understand the physics of high energy laser atmospheric propagation in adverse</p>	5.793	6.229	6.300	0.000	6.300

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602890F / <i>High Energy Laser Research</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
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<p>environmental conditions such as fog, rain, smoke and dust. Continue to evaluate and test Avoidance and Air Space De-confliction systems on directed energy test ranges. Continue to collaborate with the international directed energy community. Continue to validate predictive models through analysis of atmospheric propagation data and measurements.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.071 million. Justification for increase is described in the plans above.</p>					
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<p>Title: Directed Energy Propagation Technologies</p> <p>Description: Develop technology to support high performance beam control systems and integrated demonstrations.</p> <p>In FY 2019, this effort was named Laser Beam Control Technologies. Name changed to reflect the direction in the 2017 National Defense Authorization Act.</p> <p>FY 2019 Plans: Develop beam control technologies for directed energy weapon use on multiple platforms (aircraft, ground vehicles and shipboard systems) in stressing environments. Continue development of a predictive avoidance fire control system for use on multiple platforms. Develop kill assessment technologies. Develop hardware and technologies to improve throughput efficiency through the beam director or antenna, decrease component weight, and improve tracking and compensation through the atmosphere. Select and develop additional concepts for Service-specific applications.</p> <p>FY 2020 Base Plans: Continue to develop beam control technologies for directed energy weapon use on multiple platforms (aircraft, ground vehicles and shipboard systems) in stressing environments. Continue to development of a predictive avoidance fire control system for use on multiple platforms. Continue develop kill assessment technologies. Continue to develop hardware and technologies to improve throughput efficiency through the beam director</p>	19.660	21.158	21.936	0.000	21.936
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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602890F / <i>High Energy Laser Research</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>or antenna, decrease component weight, and improve tracking and compensation through the atmosphere. Continue select and develop additional concepts for Service-specific applications.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.778 million. Justification for increase is described in the plans above.</p>					
<p>Title: Directed Energy Lethality Research</p> <p>Description: Conduct directed energy vulnerability experiments on materials, components, and targets. Develop a lethality database, and integrate into a systems-level architecture plan and lethality models.</p> <p>In FY 2019, this effort was named High Energy Laser Lethality Research. Name changed to reflect the direction in the 2017 National Defense Authorization Act.</p> <p>FY 2019 Plans: Integrate lethality data into campaign-level directed energy system models. Conduct directed energy vulnerability experiments on materials, components, and targets. Develop a suite of directed energy weapon tools to be used in a database from which the warfighter can assess target vulnerabilities and mission utility for given directed energy weapon platform and engagement. Develop warfighter tools employing service and agencies metrics and criteria such as the Joint Munitions Effectiveness Standards.</p> <p>FY 2020 Base Plans: Continue to integrate lethality data into campaign-level directed energy system models. Continue to conduct directed energy vulnerability experiments on materials, components, and targets. Continue to develop a suite of directed energy weapon tools to be used in a database from which the warfighter can assess target vulnerabilities and mission utility for given directed energy weapon platform and engagement. Continue to develop warfighter tools employing service and agencies metrics and criteria such as the Joint Munitions Effectiveness Standards.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	3.820	4.123	4.170	0.000	4.170

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 0602890F / <i>High Energy Laser Research</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 decreased compared to FY 2019 by \$0.047 million. Justification for decrease is described in the plans above.					
<p>Title: Directed Energy Modeling</p> <p>Description: Maintain and evaluate high-fidelity engineering models for high energy laser and high power microwave system scenario evaluation and incorporation into the directed energy toolkit. Provide atmospheric propagation and directed energy system modeling for mission-level war-gaming activities.</p> <p>In FY 2019, this effort was named High Energy Laser Modeling. Name changed to reflect the direction in the 2017 National Defense Authorization Act.</p> <p>FY 2019 Plans: Provide maintenance, verification, validation, and accreditation for updated system level atmospheric propagation and directed energy system models. Collaborate with Service-sponsored field-test planning to correlate model predictions with measured data for surface, maritime and aerospace environments. Incorporate atmospheric data into theater models to support performance characterization tables. Conduct verification and validation planning to support advanced beam control objectives, diagnostics and warfighter tools.</p> <p>FY 2020 Base Plans: Continue to provide maintenance, verification, validation, and accreditation for updated system level atmospheric propagation and directed energy system models. Continue to collaborate with Service-sponsored field-test planning to correlate model predictions with measured data for surface, maritime and aerospace environments. Continue to incorporate atmospheric data into theater models to support performance characterization tables. Continue to conduct verification and validation planning to support advanced beam control objectives, diagnostics and warfighter tools.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.046 million. Justification for the increase is described in the plans above</p>	3.747	4.019	4.065	0.000	4.065
Accomplishments/Planned Programs Subtotals	40.156	43.192	44.221	0.000	44.221

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity
3600: *Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research*

R-1 Program Element (Number/Name)
PE 0602890F / *High Energy Laser Research*

D. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force / BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	0.000	138.598	124.667	0.000	124.667	121.862	130.710	136.646	139.504	Continuing	Continuing
621010: <i>Space Survivability & Surveillance</i>	-	0.000	40.187	43.123	0.000	43.123	42.698	44.780	46.021	46.668	Continuing	Continuing
624846: <i>Spacecraft Payload Technologies</i>	-	0.000	19.981	19.047	0.000	19.047	19.229	17.944	18.488	18.731	Continuing	Continuing
625018: <i>Spacecraft Protection Technology</i>	-	0.000	18.591	18.753	0.000	18.753	18.909	19.261	19.901	20.187	Continuing	Continuing
628809: <i>Spacecraft Vehicle Technologies</i>	-	0.000	59.839	43.744	0.000	43.744	41.026	48.725	52.236	53.918	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program focuses on four major areas. First, the space survivability and surveillance area develops technologies to understand space weather and the geophysics environment for mitigation and exploitation of these effects to Air Force systems. Second, the spacecraft payload technologies area improves satellite payload operations by developing advanced component and subsystem capabilities. Third, the spacecraft protection area develops technologies for protecting United States space assets in potential hostile settings. The last major area, spacecraft vehicles, focuses on spacecraft platform and control technologies, and their interactions. Efforts in this program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

In FY 2019, the entirety of PE 0602601F, Space Technology, transfers to PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only adjustment and not a new start.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602298F, 0602602F, 0602605F, and 0602788F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 2, Applied Research because this budget activity includes studies, investigations, and non-system specific technology efforts directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 2: Applied Research</i>	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	0.000	117.645	135.795	0.000	135.795
Current President's Budget	0.000	138.598	124.667	0.000	124.667
Total Adjustments	0.000	20.953	-11.128	0.000	-11.128
• Congressional General Reductions	0.000	-0.047			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	21.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• Other Adjustments	0.000	0.000	-11.128	0.000	-11.128

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 624846: *Spacecraft Payload Technologies*

Congressional Add: *Program increase - advanced materials and process for magnetic graphene memory systems*

Congressional Add Subtotals for Project: 624846

Project: 628809: *Spacecraft Vehicle Technologies*

Congressional Add: *Program increase - advanced spacecraft technologies*

Congressional Add: *Program increase - MADDIE - modular arrays for energy*

Congressional Add Subtotals for Project: 628809

Congressional Add Totals for all Projects

	FY 2018	FY 2019
Congressional Add	0.000	4.000
Congressional Add Subtotals for Project: 624846	0.000	4.000
Congressional Add	0.000	5.000
Congressional Add	0.000	12.000
Congressional Add Subtotals for Project: 628809	0.000	17.000
Congressional Add Totals for all Projects	0.000	21.000

Change Summary Explanation

Decrease in FY 2020 due to realignment of Space Science and Technology (S&T) funding from PE 1206601F, Space Technology, to PE 0603401F, Advanced Spacecraft Technology, and realignment and consolidation of Air Force Applied Research S&T funding for Future Air Force capabilities Applied Research efforts.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>				Project (Number/Name) 621010 / <i>Space Survivability & Surveillance</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
621010: <i>Space Survivability & Surveillance</i>	-	0.000	40.187	43.123	0.000	43.123	42.698	44.780	46.021	46.668	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops technologies to understand and control the space environment for warfighter's future capabilities. The focus is on characterizing and forecasting the battlespace environment for more realistic space system design, modeling, and simulation, as well as the battlespace environment's effect on space systems' performance. This includes technologies to specify and forecast the space environment for planning operations, ensure uninterrupted system performance, optimize space-based surveillance operations, and provide capability to mitigate or exploit the space environment for both offensive and defensive operations. Finally, this project includes the seismic research program that supports national requirements for monitoring nuclear explosions.

Prior to FY 2019, the entirety of Project 621010, Space Survivability and Surveillance was reported under PE 0602601F, Space Technology, Project 621010, Space Survivability and Surveillance. For FY 2019 and beyond, this project is reported under PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only change and not a new start.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Space Environment Research	0.000	14.648	20.872
Description: Develop techniques, forecasting tools, sensors, and technologies for specifying, monitoring, predicting, and controlling space environmental conditions hazardous to Department of Defense operational space and radar systems.			
In FY 2018, this work was performed under Space Environment Research effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance.			
FY 2019 Plans: Exploit data from radiation aged electrical and optical devices to enhance predictive material property model and inform development of improved spacecraft materials. Select next-generation solar particle event model for development towards operational demonstration. Select next-generation electron specification model for development towards operational demonstration. Evaluate space environment sensor and anomaly attribution tool demonstration to identify key areas for future model improvements. Assess the performance of oblique ionosonde auto scaling technologies as applied to real-time characterization of over-the-horizon-radar performance. Assess and validate advanced regional and global assimilative ionospheric models for integration into next-generation operational support. Continue to assess impacts of the arctic ionosphere on defense radar system availability. Validate integrated version of space environment impact on space-ground radio frequency links attribution tool meeting space operations requirements for scintillation and solar impacts on satellite communications, command, and control systems. Use data from the new weather satellite constellation to evaluate and refine Global Positioning			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 621010 / <i>Space Survivability & Surveillance</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>System radio frequency exploitation algorithms for global scintillation specification. Continue improvements of state-of-the-art solar magnetic flux transport model for more reliable forecast of solar radio and extreme ultraviolet flux levels, key parameters for Air Force space weather models and forecasts. Validate the advanced assimilative ionosphere-thermosphere model using these parameters. Continue work on hybrid supersonic solver code development and validation.</p> <p>FY 2020 Plans: Continue exploitation and data collection of radiation aged materials for electrical and optical property changes to enhance predictive models. Identify and initiate generation-beyond-next trapped and untrapped particle specification model development efforts. Continue space environment sensor and anomaly attribution tool demonstrations to identify key model development requirements and transition roadblocks. Research and develop technologies to exploit and mitigate space environment effects to the Department of Defense's advantage. Develop and demonstrate new ground-based and space-based sensors for monitoring and specifying the state of the space environment for military applications. Continue to develop and enhance space environment modeling capabilities to better enable accurate specification and forecasting of the state of the space environment, and the resulting impacts to Department of Defense and national systems. Advance research into the physics and dynamics of the sun to better specify and forecast solar events and better understand how those events impact the near-earth space environment. Explore fundamental radio frequency and chemical interactions in the near-earth space environment to inform potential utility for military applications. Continue work on hybrid supersonic solver code development and validation, expanding the solver to include accurate Global Positioning System performance.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$6.224 million. Funding increased due to additional development of technology in advanced space environment sensors.</p>			
<p>Title: Surveillance Technologies</p> <p>Description: Develop advanced target detection techniques, spectral signature libraries, and decision aids for space-based sensors and surveillance systems.</p> <p>In FY 2018, this work was performed under Surveillance Technologies effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance.</p> <p>FY 2019 Plans: Initiate technology development for missile warning systems, including target signatures, background phenomenology, satellite constellation architecture analyses, data analytics, and satellite demonstration concepts. Continue study of advanced surveillance and detection technologies for tracking emerging and evolving targets, including ballistic and non-ballistic targets, that pose new challenges for missile warning systems. Complete testing and transition innovative computational methods to Missile Warning System Program Office to significantly decrease satellite down-link bandwidth while maintaining high fidelity of missile warning</p>	0.000	10.880	6.049

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 621010 / <i>Space Survivability & Surveillance</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>data. Continue demonstration satellite's hypertemporal imaging mission to verify innovative advanced sensor and analytic methods for this early missile warning concept, including the collection and analysis of missile and missile like data. Provide assessment of satellite's capabilities for detecting and tracking low signature targets with complex trajectories.</p> <p>FY 2020 Plans: Initiate development of capability metrics for new satellite constellation architectures, advanced data analytics, and satellite demonstration concepts. Continue study of advanced surveillance and detection technologies for tracking emerging and evolving targets, including ballistic and non-ballistic targets that pose new challenges for missile warning systems. Document findings of innovative computational methods for Missile Warning System Program Office to significantly decrease satellite down-link bandwidth while maintaining high fidelity of missile warning data. Document findings of analysis tasks associated with on-orbit experiments that demonstrated advanced sensor and analytic methods of innovative hypertemporal imaging early missile warning concept, including the collection and analysis of missile and missile like data. Continue investigation of on-board processing capabilities and limitations for large datasets. Continue investigation of advanced surveillance and detection technologies for an expanded range of mission applications.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$4.831 million. Funding decreased due to the transition of hypertemporal imaging sensors, computational capability, and employment techniques.</p>			
<p>Title: Radiation Remediation Research</p> <p>Description: Conduct Radiation Belt Remediation research through development and validation of analytical performance models for remediation of Earth radiation belts following high altitude nuclear detonation.</p> <p>In FY 2018, this work was performed under Radiation Remediation Research effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance.</p> <p>FY 2019 Plans: Continue space experiment operations, reduction and science data exploitation to finalize the validation of the end-to-end model for space-based remediation systems. Previously planned FY 2019 space experiment work moved to FY2020 due to change in space experiment launch date.</p> <p>FY 2020 Plans: Complete space experiment operations, and reduction and exploitation of data sets to finalize end-to-end model validation. Conduct assessment of feasibility and system requirements for space-based and combined ground and space-based remediation systems.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	0.000	0.100	1.799

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 621010 / <i>Space Survivability & Surveillance</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$1.669 million. Funding increased due to adjustment of space experiment launch date				
<p>Title: Seismic Technologies</p> <p>Description: Develop seismic technologies to support national requirements for monitoring nuclear explosions with special focus on regional distances less than 2,000 kilometers from the sensors.</p> <p>In FY 2018, this work was performed under Seismic Technologies effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance.</p> <p>FY 2019 Plans: Test new algorithms on high performance computing capabilities to improve automation of the detection, location, and discrimination of seismic events. Assess earth models for use in high-performance computing modeling and simulation codes for operational expert analysis of difficult-to-discriminate earthquakes and explosions. Test specific algorithms for application of big data heuristics to more quickly characterize seismic events. Explore new statistical approaches to the behavior of discriminants for local (less than 200 kilometers) and regional (less than 2,000 kilometers) seismic events.</p> <p>FY 2020 Plans: Test new algorithms on high performance computing capabilities with special focus on improving earth structure models and the resulting automation of the discrimination of seismic events. Exercise earth models in use in high-performance computing modeling and simulation codes for operational expert analysis of difficult-to-discriminate earthquakes and explosions. Continue to test specific algorithms for application of big data heuristics to more quickly characterize seismic events. Further develop new statistical approaches to the behavior of discriminants for local (less than 200 kilometers) and regional (less than 2,000 kilometers) seismic events.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.134 million. Justification for the decrease is described in the plans above.</p>		0.000	5.972	5.838
<p>Title: Alternative Navigation Technologies</p> <p>Description: Develop new technologies based on cold atom physics that provide autonomous jam-proof precision inertial navigation to augment Global Positioning System in case of Global Positioning System-denial. Develop atomic clocks based on new technologies to replace legacy Global Positioning System atomic clocks.</p> <p>In FY 2018, this work was performed under Alternative Navigation Technologies effort in PE 0602601F, Space Technology, Project 621010, Space Survivability & Surveillance.</p> <p>FY 2019 Plans:</p>		0.000	8.587	8.565

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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 621010 / <i>Space Survivability & Surveillance</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Complete testing of advanced compact atomic clocks with improved accuracy and stability to replace legacy atomic clocks. Complete packaging of system for flight on experimental satellite system. Continue transition of advanced compact atomic clocks to industry. Begin testing of free-space, cold atom 3-axis gyroscope/accelerometer that will enable Global Positioning System free precision navigation. Start packaging of system for test on aircraft flight experiment or other suitable platform.</p> <p><i>FY 2020 Plans:</i> Complete rad-hard component development for advanced compact atomic clocks with improved accuracy and stability to replace legacy atomic clocks. Deliver system for integration onto experimental satellite system. Continue transition of advanced atomic clocks to industry with potential on ramp onto future satellites. Continue testing of cold atom 3-axis accelerometers for improved Internal Navigation Systems in Global Position System denied environments.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$ 0.022 million. Justification for the decrease is described in the plans above.</p>			
Accomplishments/Planned Programs Subtotals	0.000	40.187	43.123

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>				Project (Number/Name) 624846 / <i>Spacecraft Payload Technologies</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
624846: <i>Spacecraft Payload Technologies</i>	-	0.000	19.981	19.047	0.000	19.047	19.229	17.944	18.488	18.731	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops advanced technologies that enhance spacecraft payload operations by improving component and subsystem capabilities. The project focuses on development of advanced, space-qualified, survivable electronics, and electronics packaging technologies; development of advanced space data generation and exploitation technologies, including infrared sensors; and development of high-fidelity space simulation models that support space-based surveillance and space asset protection research and development for the warfighter.

Prior to FY 2019, the entirety of Project 624846, Spacecraft Payload Technologies, was reported under PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies. For FY 2019 and beyond, this project is reported under PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only change and not a new start.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Space-Based Detector Technologies	0.000	3.230	3.931
Description: Develop advanced infrared device technologies that enable hardened space detector arrays with improved detection to perform acquisition, tracking, and discrimination of space objects and missile warning.			
In FY 2018, this work was performed under Space-Based Detector Technologies effort in PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies.			
FY 2019 Plans: Delivery of an 8000 x 8000, 10 micrometer pitch focal plane arrays that will be hardened to the natural space environment as well as focused photons. Upon delivery of said hardware it will be characterized in representative environment to verify functionality and if any shortfalls arise they will be addressed with iterative development. This will enable whole earth staring for the Launch Detection and Missile Warning mission.			
FY 2020 Plans: Begin design, development, and assessment of low-cost, high-volume infrared detectors and focal plane arrays for proliferated space architecture layers. Begin development of focal plane array optical data outputs for higher speed and data throughput and begin radiation tolerance characterization of photonic devices. Begin development of alternative infrared focal plane array materials and device architectures. Continue development of resilient scanning and staring digital focal plane arrays. Complete			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 624846 / <i>Spacecraft Payload Technologies</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
development of 8192 x 8192 pixels, 10 micron pixel pitch focal plane arrays hardened to the natural space environment and focused photons to enable whole-earth staring for Launch Detection and Missile Warning missions. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.701 million. Justification for the increase is described in the plans above.			
Title: Space Electronics Research Description: Develop technologies for space-based payload components such as radiation-hardened electronic devices, microelectro-mechanical system devices, and advanced electronics packaging. In FY 2018, this work was performed under Space Electronics Research effort in PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies. FY 2019 Plans: Continue leadership role in Deputy Assistant Secretary of Defense Systems Engineering risk reduction strategy by development of trusted manufacturing techniques that reduce risk to National Security Strategy systems. Continue to benchmark advanced algorithms on state-of-the-art electronics and transition results to acquisition community to enable data-informed architecture design decisions. Expanding capability to include assessments of classified requirements. Continue planning qualification efforts for next generation space processor. Continue research and development on ultra-low power and neuromorphic processing architectures to enable game-changing capabilities in future National Security Space systems. Continue development of alternative memory approaches for high density memory for use in space-based systems. Continue advanced transistor development, and transitioning techniques to mainstream manufacturing. FY 2020 Plans: Continue leadership role in Deputy Assistant Secretary of Defense Systems Engineering trusted and assured microelectronics strategy efforts by development of trusted manufacturing techniques that reduce risk to National Security Space systems. Improving benchmarking capabilities on state-of-the-art electronics using latest spacecraft algorithms and transitioning results to acquisition community to enable data-informed payload architecture design decisions. Initiating complete space qualification planning for next generation space processor and begin implementing plan. Continue development of alternative memory approaches for high density memory needed for next-generation space systems. Continue research and development of ultra-low power and neuromorphic/cortical processing architectures to enable game-changing capabilities in future National Security Space systems. Continue advanced transistor research and development, and transitioning techniques to mainstream manufacturing. FY 2019 to FY 2020 Increase/Decrease Statement:	0.000	2.764	4.429

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 624846 / <i>Spacecraft Payload Technologies</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$ 1.665 million. Funding increase due to additional emphasis on radiation hardened space electronics to enable resilient operations in contested space.				
<p>Title: Modeling and Simulation Tools for Space Applications</p> <p>Description: Develop modeling and simulation tools for space-based ground surveillance systems, rendezvous and proximity operations, imaging of space systems, disaggregated satellite architecture, and space control payloads.</p> <p>In FY 2018, this work was performed under Modeling and Simulation Tools for Space Applications effort in PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies.</p> <p>FY 2019 Plans: Conduct mission-level military utility analyses of various space sensing, satellite navigation, space control, and communication architecture approaches. Refine guidelines and checkpoints to evaluate maturity and applicability of emerging space technologies to support various Air Force Research Laboratory technical programs, Department of Defense customers and wargame events. Continue development of models and mission simulations enabling analysis of contested space environment and space enterprise capabilities. Progress the development of baseline modeling and simulation capabilities to support quick-turn analysis and trade studies.</p> <p>FY 2020 Plans: Complete mission-level military utility analyses of architecture approaches across multi-domain mission areas. Continue refining guidelines and checkpoints for concept maturation evaluations in context of emerging space technologies. Continue development of models and mission simulations of the National Space Defense Center's new space and space enterprise capabilities.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.215 million. Justification for the increase is described in the plans above.</p>		0.000	5.403	5.618
<p>Title: Alternative Positioning, Navigation, and Timing Technology</p> <p>Description: Identify and develop technologies that enable new, or enhance existing, United States positioning, navigation, and timing satellite capabilities by increasing resiliency and availability of accuracy, and/or increasing the affordability of providing current capabilities. Develop technologies to meet identified Air Force Space Command/Space and Missile Systems Center positioning, navigation, and timing space payload technology needs.</p> <p>In FY 2018, this work was performed under Alternative Positioning, Navigation, and Timing Technology effort in PE 0602601F, Space Technology, Project 624846, Spacecraft Payload Technologies.</p> <p>FY 2019 Plans:</p>		0.000	4.584	5.069

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 624846 / <i>Spacecraft Payload Technologies</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Begin characterization of amplifiers, multiplexers and digital waveform generators being developed under Small Business Innovation Research Phase II contracts. Continue studies to identify alternative and innovative technologies that are viable for positioning, navigation, and timing payloads and ground systems and to investigate advanced signal and system concepts. Begin integration of positioning, navigation, and timing payload components developed under various contracts into positioning, navigation, and timing payloads to explore the concept of positioning, navigation, and timing payload modularity.</p> <p>FY 2020 Plans: Develop advanced Precision Navigation and Timing waveforms and begin to examine the interaction of signals between the space, ground, and user equipment segments. Explore new technologies for positioning, navigation, and timing payloads that will improve performance and affordability. Continue studies that explore technologies for multi-layer space-based positioning, navigation, and timing architecture in order to improve resiliency of the space architecture. Work to develop modeling and simulation results of next generation space architecture and the impact of developing technologies.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.485 million. Justification for the increase is described in the plans above.</p>			
Accomplishments/Planned Programs Subtotals	0.000	15.981	19.047

	FY 2018	FY 2019
Congressional Add: Program increase - advanced materials and process for magnetic graphene memory systems	0.000	4.000
FY 2018 Accomplishments: Not applicable		
FY 2019 Plans: Conduct Congressionally directed effort		
Congressional Adds Subtotals	0.000	4.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>				Project (Number/Name) 625018 / <i>Spacecraft Protection Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
625018: <i>Spacecraft Protection Technology</i>	-	0.000	18.591	18.753	0.000	18.753	18.909	19.261	19.901	20.187	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops the technologies for protecting United States space assets in potentially hostile environments to assure continued space system operation without performance loss in support of warfighter requirements. The project focuses on identifying and assessing spacecraft system vulnerabilities, developing threat warning technologies, and development of technologies to mitigate the effects of both intentional and unintentional threats.

Prior to FY 2019, the entirety of Project 625018, Spacecraft Protection Technology, was reported under PE 0602601F, Space Technology, Project 625018, Spacecraft Protection Technology. For FY 2019 and beyond, this project is reported under PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only change and not a new start.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Threat Warning Research	0.000	18.591	18.753
Description: Develop satellite threat warning technologies and tools for space defense. Exploit on-board inherent satellite resources, satellite-as-a-sensor, and self-aware satellite technologies. Develop technologies to detect, assess, and respond to threats and anomalies.			
In FY 2018, this work was performed under Threat Warning Research effort in PE 0602601F, Space Technology, Project 625018, Spacecraft Protection Technology.			
FY 2019 Plans: Develop techniques to detect, track, identify, and characterize satellites using multi-phenomenology to address gaps in knowledge for space situational awareness. Consider the tasking, collection, processing, exploitation and dissemination needs. Assess timeliness and persistence of space situational awareness capability and develop techniques that address the growing number of objects that must be monitored. Develop techniques to mitigate the growing population of objects that need to be monitored, from newly launched objects to debris. Assess utilizing commercial and international space situational awareness sources. Continue maturation of the space resiliency testbed to enhance ability to conduct full-spectrum space control RED-vs-BLUE experimentation with ops, network, command and control, and hardware in the loop. Conduct space cyber experimentation using on-orbit science satellite. Initiate research into advanced methods for net-centric space command and control architectures, to include cloud-based paradigms and other advanced computational methods across the full scope of the ground and space-based enterprise. Continue development of advanced algorithms for sensor data fusion and satellite threat detections, assessment, response and protection. Complete space situational awareness-focused data analysis methods including physics-based sensor			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 625018 / <i>Spacecraft Protection Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>model development for data filtering and space command and control architectures. Complete advancing filtering techniques accommodating nonlinear dynamics and non-normal random variable distributions. Mature concepts of new electro-optical and radio frequency sensors for space object identification and characterization. Continue incorporating customer feedback of closed loop sensor tasking concept for space surveillance, combining commercial and government sensor assets. Continue assessment and development of commercial remote sensing data and information to fill gaps in coverage for monitoring and tracking ground and space objects. Continue engagements and methods development with commercial space data providers for testing new enabling technologies on commercial satellites.</p> <p>FY 2020 Plans: Continue to develop techniques to detect, track, identify, and characterize satellites using multi-phenomenology to address gaps in knowledge for space situational awareness and consider the tasking, collection, processing, exploitation and dissemination needs. Assess timeliness and persistence of space situational awareness capability and develop techniques to mitigate the growing population of objects that need to be monitored, from newly launched objects to debris. Conduct cooperative development utilizing commercial and international space situational awareness sources. Initiate research and development on an integrated ground and space indications and warnings experiment. Utilize space resiliency testbed to integrate technology solutions, and evaluate effectiveness against notional threats to our space architectures. Develop cyber hardening technologies, and integrate space and cyber operations capabilities. Conduct end-to-end evaluations and hardware-in-the-loop experiments for threat warning and response capabilities for protection of high value space assets. Conduct experiments, integrating commercial space Command and Control capabilities into Department of Defense ground architectures. These capabilities include real-time mission planning, utilization of non-traditional Intel sources (i.e. social media), multi-path communications architectures, etc. Develop and demonstrate autonomous technologies using net-centric space command and control architectures for multi-domain command and control across the full scope of the ground and space-based enterprise. Continue development and demonstration of advanced algorithms for sensor data fusion and satellite threat detection, assessment, and response. Investigate, implement, and demonstrate integrated command and control systems at the tactical, operational, and strategic levels. Continue assessment and development of commercial capability in order to either augment or replace traditional methods for space related command and control. Continue engagements with commercial space data providers for testing new enabling technologies on commercial satellites. Continue to develop on-board autonomous satellite technologies and plan for next generation flight experiments.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.162 million. Justification for increase is described in the plans above.</p>			
Accomplishments/Planned Programs Subtotals	0.000	18.591	18.753

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 625018 / <i>Spacecraft Protection Technology</i>

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 2					R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>				Project (Number/Name) 628809 / <i>Spacecraft Vehicle Technologies</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
628809: <i>Spacecraft Vehicle Technologies</i>	-	0.000	59.839	43.744	0.000	43.744	41.026	48.725	52.236	53.918	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project focuses on spacecraft platforms (for example: structures, power, and thermal management); satellite control (signal processing and control); and space experiments of maturing technologies for space qualification.

Prior to FY 2019, the entirety of Project 628809, Spacecraft Vehicle Technologies, was reported under PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies. For FY 2019 and beyond, this project is reported under PE 1206601F, Space Technology, to provide increased transparency to the Office of the Secretary of Defense and Congress regarding Space Science and Technology Major Force Program 12 Space investment. This is an administrative only change and not a new start.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Space Power/Thermal Research	0.000	4.804	4.095
Description: Develop technologies for advanced space platform subsystems such as cryocoolers, compact, high efficiency solar power cells and arrays, and innovative power generation concepts.			
In FY 2018, this work was performed under Space Power/Thermal Research effort in PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies.			
FY 2019 Plans: Continue research into advanced space solar cells, solar array, and energy storage technologies. Continue research into approaches for greater than 40% solar cell efficiency. Begin evaluation of approaches for high radiation orbit optimized solar cells. Continue development of advanced array technologies to meet 70-80 kilowatt per cubic meter array performance. Initiate research incorporating photon management schemes into III-V devices for increased efficiency and end of-life. Initiate cell level resiliency research efforts. Develop panel level resilient approaches.			
FY 2020 Plans: Continue research into advanced space solar cells, solar array, and energy storage technologies. Focus on support for current heritage space systems, while also pivoting towards support of smaller space vehicles that will be utilized for the Space Warfighting Construct. Improve solar cells end of life performance to above 28% power conversion efficiency. Develop solar array structures tailored for small to large missions with specific power greater than 100 watts per kilogram. Develop energy storage			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 628809 / <i>Spacecraft Vehicle Technologies</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>chemistries with cell-level specific energy greater than 300 watt-hours per kilogram. Further develop array hardening approaches to provide drop-in replacement panels.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.709 million. Justification for the decrease is described in the plans above.</p> <p>Title: Space Structures and Controls Research</p> <p>Description: Develop revolutionary and enabling technologies, including lighter weight, lower cost, high performance structures for space platforms; guidance, navigation, and controls hardware and software for next generation of space superiority systems.</p> <p>In FY 2018, this work was performed under Space Structures and Controls Research effort in PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies.</p> <p>FY 2019 Plans: Continue reactive maneuver strategies for spacecraft resiliency in laboratory simulation and initiate high-fidelity simulations/breadboards. Continue research in verification and validation techniques for autonomous spacecraft flight software. Continue improved estimation algorithms for on-orbit navigation software. Initiate laboratory and high-fidelity simulations/breadboard implementation for navigation algorithms with hardware-in-the-loop. Transition development of United States space asset protection, threat identification, and mitigation technologies including deployable structures, structural sensing, and thermal technologies to advanced development and flight experimentation. Perform test bed develop and integrated proof-of-concept experiments for advanced, agile manufacturing and assembly technologies for satellite production to improve performance and affordability. Continue research efforts in high-power small satellite technologies and affordable, high-performance phased arrays and electrically steerable antennas for tactical communication and radar concepts for agile, intelligent targets. Initiate research in functionalized structures using multi-material additive manufacturing.</p> <p>FY 2020 Plans: Continue reactive maneuver strategies for spacecraft resiliency in hardware-in-the-loop testbeds. Initiate on-orbit experiment planning for reactive maneuver strategies. Apply research in verification and validation techniques for autonomous spacecraft flight software to high-fidelity simulations and breadboard laboratory experiments. Apply improved estimation algorithms for on-orbit navigation software to experimental data to assess performance and robustness. Complete laboratory and high-fidelity simulations/breadboard implementation for navigation algorithms and assess progress towards flight experiment demonstration. Continue development of integrated proof-of-concept experiments for advanced, agile manufacturing and assembly technologies for satellite production to improve performance and affordability. Continue research in functionalized structures using multi-material additive manufacturing. Transition development of research efforts in high-power small satellite technologies and</p>	0.000	9.007	10.598

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 628809 / <i>Spacecraft Vehicle Technologies</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
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affordable, high-performance phased arrays and electrically steerable antennas for tactical communication and radar concepts for agile, intelligent targets to advanced development and flight experimentation.

FY 2019 to FY 2020 Increase/Decrease Statement:

FY 2020 increased compared to FY 2019 by \$1.591 million. Funding increased due to additional development of responsive satellite maneuver capabilities.

<i>Title:</i> Space Experiments	0.000	21.705	22.915
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Description: Develop flight experiments to improve the capabilities of existing operational space systems and to enable new transformational space capabilities.

In FY 2018, this work was performed under Space Experiments effort in PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies.

FY 2019 Plans:

Continue and complete one year of experimental satellite on-orbit operations. Complete program and close-out. Conclude on-orbit testing and verification of a fourth geosynchronous orbit based missile warning payload to demonstrate hypertemporal imaging capabilities to detect missile launches under sun-lit clouds, potentially enabling all weather early missile detection. Conclude on-orbit testing and verification of an integrated, on-board sensing, assessment, and autonomy technology demonstration payload at geosynchronous orbit, demonstrating geosynchronous orbit asset resiliency to a specific set of on-orbit events enabling system mission assurance in a degraded space environment. On-orbit demonstration of the first geosynchronous orbit CubeSat providing enhanced capability to the space enterprise. On-orbit demonstration of three formation flying satellites for near autonomous formation control. Refine on-orbit experiment plan and mission objectives to align with payload development progress, and continue developing data requirements and risk management plan for space-based integrated demonstration of an advanced Global Positioning System payload for contested environments.

FY 2020 Plans:

Conduct on-orbit small satellite demonstration of the first ever Link-16 from space to the tactical user enabling a Common Operating Picture for the Warfighter in a contested/degraded environment in support of Multi-Domain Command and Control. On-orbit small satellite demonstration capable of measuring radiation in the inner magnetosphere giving insight into the particle radiation space environment. Conduct a flight selection process and perform trade studies to determine the next flight experiment(s). Develop and mature a reference design, technical objectives, and experiment plan in coordination with Air Force Space Command, Space and Missile Systems Center and/or other mission partners. Begin working long term items such as contracting strategy, parts, frequency allocation, and information assurance strategies.

FY 2019 to FY 2020 Increase/Decrease Statement:

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 628809 / <i>Spacecraft Vehicle Technologies</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
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FY 2020 increased compared to FY 2019 by \$1.210 million. Funding increase due to accelerated demonstration of small satellite technologies.

Title: Space Communication Technologies	0.000	7.323	6.136
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Description: Develop technologies for next-generation space communications terminals and equipment and methods/techniques to enable future space system operational command and control concepts.

In FY 2018, this work was performed under Space Communication Technologies effort in PE 0602601F, Space Technology, Project 628809, Spacecraft Vehicle Technologies.

FY 2019 Plans:

Support launch of W and V frequency band flight instrument. Support execution of a W and V band propagation experiment. Conduct research and development to address future military satellite communications capability and technology needs, for example, high-gain antenna, high-power amplifiers, low-noise amplifiers, cognitive / resilient networks, reconfigurable satellite radios / transponders, and anti-jam signal processing technologies. Support development and demonstration of novel laser communications technology.

FY 2020 Plans:

Support W/V-band payload operations, telemetry analysis, and health and status monitoring. Continue to develop and conduct technology demonstrations to address future military satellite communications capability and technology needs, for example, high-gain antenna, high-power amplifiers, low-noise amplifiers, cognitive / resilient networks, reconfigurable satellite radios / transponders, and anti-jam signal processing technologies. Support development and demonstration of novel laser communications technologies such as multi-wave length optical routers. Develop network traffic models, multi-spacecraft network models, and spacecraft network simulation support, along with analysis/visualization tools to aid.

FY 2019 to FY 2020 Increase/Decrease Statement:

FY 2020 decreased compared to FY 2019 by \$1.187 million. Funding decreased due to transition of the W/V-band technology development to a flight demonstration.

Accomplishments/Planned Programs Subtotals	0.000	42.839	43.744
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	FY 2018	FY 2019
Congressional Add: Program increase - advanced spacecraft technologies	0.000	5.000
FY 2018 Accomplishments: Not applicable		
FY 2019 Plans: Conduct Congressionally directed effort		
Congressional Add: Program increase - MADDIE - modular arrays for energy	0.000	12.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 2	R-1 Program Element (Number/Name) PE 1206601F / <i>Space Technology</i>	Project (Number/Name) 628809 / <i>Spacecraft Vehicle Technologies</i>
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	FY 2018	FY 2019
FY 2018 Accomplishments: Not applicable		
FY 2019 Plans: Conduct Congressionally directed effort		
Congressional Adds Subtotals	0.000	17.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	34.694	47.426	36.586	0.000	36.586	38.181	38.770	39.667	40.553	Continuing	Continuing
632100: <i>Laser Hardened Materials</i>	-	15.930	14.786	15.807	0.000	15.807	16.739	16.304	16.698	17.084	Continuing	Continuing
633153: <i>Non-Destructive Inspection Development</i>	-	3.507	6.375	6.501	0.000	6.501	6.631	6.659	6.843	7.020	Continuing	Continuing
633946: <i>Materials Transition</i>	-	15.257	26.265	14.278	0.000	14.278	14.811	15.807	16.126	16.449	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops and demonstrates advanced materials technologies that enhance protection for Air Force aircrews to ensure safety and to enable aircrews to perform required missions in threat environments. Advanced materials technologies are also developed and demonstrated to enhance protection for Air Force sensors and systems to ensure safety, survivability, and operability in threat environments.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity	R-1 Program Element (Number/Name)
3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	PE 0603112F / <i>Advanced Materials for Weapon Systems</i>

B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	37.856	34.426	36.584	0.000	36.584
Current President's Budget	34.694	47.426	36.586	0.000	36.586
Total Adjustments	-3.162	13.000	0.002	0.000	0.002
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	13.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-0.022	0.000			
• SBIR/STTR Transfer	-0.970	0.000			
• Other Adjustments	-2.170	0.000	0.002	0.000	0.002

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 633946: *Materials Transition*

Congressional Add: *Program increase - Materials Transition of Metals for Hypersonics*

Congressional Add: *Program increase - Metals Affordability Research*

Congressional Add Subtotals for Project: 633946

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	0.000	3.000
	0.000	10.000
Congressional Add Subtotals for Project: 633946	0.000	13.000
Congressional Add Totals for all Projects	0.000	13.000

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>				Project (Number/Name) 632100 / <i>Laser Hardened Materials</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
632100: <i>Laser Hardened Materials</i>	-	15.930	14.786	15.807	0.000	15.807	16.739	16.304	16.698	17.084	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates advanced materials technologies that enhance protection for Air Force aircrews to ensure safety and to enable aircrews to perform required missions in threat environments. Advanced materials technologies are also developed and demonstrated to enhance protection for Air Force sensors and systems to ensure safety, survivability, and operability in threat environments.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Aerospace Systems Protection	7.960	6.949	7.429	0.000	7.429
Description: Develop and demonstrate materials technologies that enhance hardening for sensors, avionics, and components to increase survivability and mission effectiveness of aerospace systems.					
FY 2019 Plans: Continue to validate and continue to develop protection materials for visual/Near Infrared (NIR) Intelligence, Surveillance, & Reconnaissance (ISR) sensors. Assess the demonstrated results and pursue the use of protection technologies for future sensor designs and strategies to mitigate directed energy damage for NIR, Space, Shortwave Infrared Midwave(SWIR), and Midwave Infrared (MWIR) detectors. Apply gained technologies and integrate the developments into survivable electro-optic sensors that provide full spectrum protection for missile warning. Analyze the performance impact of damage-limiting semiconductor materials designed to harden electro-optic imaging sensors. Continue transition of developed laser countermeasures for survivability of dynamic electro-optic/infrared imagers. Continue to advance the employment and integration of evolved computational materials science to model materials characteristics to increase accuracy and shorten design cycle time of coatings development for use in sensor hardening. Continue technology stimulation and maturation to develop defensive capability for air systems airframe and anti-access munitions hardening assessments and solutions.					
FY 2020 Base Plans: Demonstrate, validate and continue to develop protection materials for visual/NIR ISR sensors. Assess the demonstrated results and transition the use of protection technologies for future sensor designs and strategies to mitigate directed energy damage for visual/NIR, SWIR, and MWIR detectors. Transition gained technologies and integrate the developments into light, operator friendly survivable electro-optic sensors that provide full					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>	Project (Number/Name) 632100 / <i>Laser Hardened Materials</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
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<p>spectrum protection for missile warning. Continue analyzing the high-performance properties of damage-limiting semiconductor materials designed to harden electro-optic imaging sensors. Transition developed laser countermeasures for survivability of dynamic electro-optic/infrared imagers. Advance the employment and integration of evolved computational materials science to model materials characteristics to increase accuracy and shorten design cycle time of coatings development for use in sensor hardening. Transition and continue technology development and maturation to develop defensive capability for air systems airframe and anti-access munitions hardening assessments and solutions.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.480 million. Justification for the increase is described in the plans above.</p>					
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<p>Title: Aircrew Protection</p> <p>Description: Develop and demonstrate materials technologies that enhance protection for Air Force aircrews to ensure safety and to enable aircrews to perform required missions in a threat environment.</p> <p>FY 2019 Plans: Continue to develop, validate, and demonstrate laser protection materials and technologies for personnel protection. Continue to validate and develop helmet-mounted sensor hardening materials focusing on next-generation nighttime sensors. Continue to advance development of visor based aircrew protection materials with agile protection. Continue to evaluate advances in characterization and demonstration of eye protection technologies using computational materials science tools. Continue to validate, mature, and test improvements to functionality and performance of personnel protection technologies in expected operational conditions.</p> <p>FY 2020 Base Plans: Continue to develop, validate, demonstrate, and transition laser protection materials and technologies for personnel protection. Continue to validate and develop light-weight helmet-mounted sensor hardening materials focusing on next-generation nighttime specialized sensors. Advance transition efforts and development of visor based aircrew protection materials with agile protection. Evaluate and assess new materials and advances in characterization and demonstration of eye protection technologies using computational materials science tools. Transition, validate, mature, and test improvements to functionality and performance of personnel protection</p>	7.970	7.837	8.378	0.000	8.378
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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>	Project (Number/Name) 632100 / <i>Laser Hardened Materials</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
technologies in expected operational conditions. Continue development and testing of materials technologies to protect against nuclear flash blindness. <i>FY 2020 OCO Plans:</i> Not Applicable <i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.541 million. Justification for the increase is described in the plans above.					
Accomplishments/Planned Programs Subtotals	15.930	14.786	15.807	0.000	15.807

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>				Project (Number/Name) 633153 / <i>Non-Destructive Inspection Development</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
633153: <i>Non-Destructive Inspection Development</i>	-	3.507	6.375	6.501	0.000	6.501	6.631	6.659	6.843	7.020	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates advanced nondestructive inspection and evaluation (NDI/E) technologies to monitor performance integrity and to detect failure causing conditions in weapon systems components and materials. NDI/E capabilities greatly influence and/or limit many design, manufacturing, and maintenance practices. This project provides technology to satisfy Air Force requirements to extend the lifetime of current systems through increased reliability and cost-effectiveness at field and depot maintenance levels. Equally important is assuring manufacturing quality, integrity, and safety requirements.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Advanced Engine Inspection Technologies	0.810	1.594	1.625	0.000	1.625
Description: Develop and demonstrate advanced technologies to improve capabilities to inspect for cracks and other damage to extend the total safe life of turbine engines.					
FY 2019 Plans: Continue to develop nondestructive inspection/evaluation approaches to assess materials and damage state of critical turbine engine components for the purpose of extending the useful life without increasing risk of in-flight failure of fracture critical to gas turbine engine components. Continue to assess model prediction, accuracy, and effectiveness of digital nondestructive inspection technologies and demonstrate tool automation for high confidence repeatable results.					
FY 2020 Base Plans: Continue nondestructive inspection/evaluation approaches to include additive manufacturing and to assess materials and damage state of critical turbine engine components for the purpose of extending the useful life without increasing risk of in-flight failure of fracture critical to gas turbine engine components. Advance the validation process for model prediction, accuracy, and effectiveness of digital nondestructive inspection technologies and demonstrate tool automation for high confidence repeatable results, to include advanced manufacturing processes.					
FY 2020 OCO Plans: Not Applicable					
FY 2019 to FY 2020 Increase/Decrease Statement:					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force			Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>	Project (Number/Name) 633153 / <i>Non-Destructive Inspection Development</i>			
B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 increased compared to FY 2019 by \$0.031 million. Justification for the increase is described in the plans above.					
<p>Title: Special Material Inspection Technologies (formerly known as "Low-Observable Inspection Technologies")</p> <p>Description: Develop and demonstrate advanced inspection technologies supporting low-observable (LO) systems to enhance affordability and ensure full performance and survivability.</p> <p>FY 2019 Plans: Continue to transition improved methods to acquire and analyze data to facilitate improved characterization, registration, and tracking of degradation and damage of special materials that enables/ensures more affordable coatings assessment. Continue to validate tools to improve characterization of specialty multilayer coatings. Continue to develop robotic technologies for visual inspections that will realize human-assisted inspection capabilities and begin to provide capabilities for automated multi-spectral characterization.</p> <p>FY 2020 Base Plans: Continue the transition process to depots and flight lines for improved methods to acquire and analyze data to facilitate improved characterization, registration, and tracking of degradation and damage of special materials that enables/ensures more affordable coatings assessment. Validate tools to improve characterization and failure modes of specialty multilayer coatings. Continue to develop automation for robotic technologies for visual inspections that will realize human-assisted inspection capabilities and begin to provide capabilities for automated multi-spectral characterization.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.024 million. Justification for the increase is described in the plans above.</p>	0.847	1.211	1.235	0.000	1.235
<p>Title: Advanced System Monitoring Technologies</p> <p>Description: Develop and demonstrate advanced systems status monitoring technologies to provide on-board and embedded sensing to gain continuous awareness of the state of key subsystems.</p> <p>FY 2019 Plans:</p>	1.850	3.570	3.641	0.000	3.641

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force			Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>	Project (Number/Name) 633153 / <i>Non-Destructive Inspection Development</i>			
B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Continue demonstrating analytical methods to assess the location of damage in multi-layered structure base on nondestructive inspection data and results. Continue to transition robotic nondestructive inspection methods to minimize disassembly and reduced maintenance burden to perform inspections of aircraft structures. Continue development of novel approaches to collect, analyze, transport, archive, and use digital nondestructive inspection data and information. Continue enhanced methods for collecting and analyzing digital Non-Destructive Inspection/Evaluation (NDI/E) data necessary for improved damage detection and characterization. Continue the integration of computational materials science tools with life prediction methods to enable risk-based life management.</p> <p><i>FY 2020 Base Plans:</i> Continue to demonstrate advanced analytical methods to more accurately assess the location, and register spatial location, of damage detected using nondestructive inspection data and results. Continue to transition automated robotic nondestructive inspection methods to minimize disassembly and reduced maintenance burden to perform inspections of aircraft structures. Continue development and transition of novel approaches to collect, analyze, transport, archive, and use digital nondestructive inspection data and information. Continue enhanced methods for compiling, reporting, collecting and rapidly analyzing digital Non Destructive Testing/Evaluation (NDI/E) data necessary for improved damage detection and characterization. Continue the transition and integration of computational materials science tools with life prediction methods to enable risk-based life management.</p> <p><i>FY 2020 OCO Plans:</i> Not Applicable</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.071 million. Justification for the increase is described in the plans above.</p>					
Accomplishments/Planned Programs Subtotals	3.507	6.375	6.501	0.000	6.501
C. Other Program Funding Summary (\$ in Millions)					
N/A					
Remarks					
D. Acquisition Strategy					
N/A					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>	Project (Number/Name) 633153 / <i>Non-Destructive Inspection Development</i>

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>				Project (Number/Name) 633946 / <i>Materials Transition</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
633946: <i>Materials Transition</i>	-	15.257	26.265	14.278	0.000	14.278	14.811	15.807	16.126	16.449	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates advanced materials and processing technologies for fielded and planned Air Force weapon, airframe, and propulsion applications. Advanced materials and processes that have matured beyond applied research are characterized, critical data are collected, and critical evaluations in the proposed operating environment are performed. This design and scale-up data improves the overall affordability of promising materials and processing technologies, providing needed initial incentives for their industrial development.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Air Vehicle Materials Technologies	12.770	11.065	8.136	0.000	8.136
Description: Develop and demonstrate materials and processes technologies for air vehicle and subsystems to enhance lift, propulsion, Low-Observable (LO) performance, power generation management, and affordability of air vehicles.					
FY 2019 Plans: Transition magneto-resistive sensing and materials and processes to increase special materials affordability. Continue development of advanced directed energy protection technologies. Continue development of technologies for electromagnetic hardening acquisition and field support. Continue development of technologies for organic engine lifing analysis for enhanced engine component risk management capability.					
FY 2020 Base Plans: Continue development and transition of advanced directed energy protection technologies. Continue development of advanced technologies for electromagnetic hardening acquisition and field support. Assess date, compile, report and continue development of technologies for organic engine lifing analysis for enhanced engine component risk management capability. Transition development of materials to protect infrared apertures on next generation hardened assets. Validate and verify results of microstruture-sensitive lifing methodologies that lower life cycle cost and advance performance characteristics of airframe and engine components in order to initiate development of next generation modeling tools that incorporate residual stress effects on component life.					
FY 2020 OCO Plans: Not Applicable					
FY 2019 to FY 2020 Increase/Decrease Statement:					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force			Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>	Project (Number/Name) 633946 / <i>Materials Transition</i>			
B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 decreased compared to FY 2019 by \$2.929 million. Funding decreased due to higher Technology Readiness Level achievement of organic life analysis.					
<p>Title: High Temperature Material Technologies</p> <p>Description: Develop and demonstrate affordable, novel high temperature materials/structures and thermal management concepts to enable future defense capabilities for prompt global strike concepts.</p> <p>FY 2019 Plans: Continue work on multimaterial structures that optimally address operational temperature zones for hot structure and expendable thermal protection systems made out of advanced ceramics, ceramic matrix composites, hybrids, advanced and affordable metals, and intermetallics. Transition 2700-degree Fahrenheit ceramic matrix composites for turbine hot section components to industry. Continue to develop high performance and affordable metals for next-generation turbine disk and low cost propulsion, aerostructure and munitions components. Continue development of low cost metallic turbine engine disks made via powder processing technologies for use in high temperature, aggressive environment.</p> <p>FY 2020 Base Plans: Continue to work on multimaterial structures that optimally address operational temperature zones for hot structure and expendable thermal protection systems made out of advanced ceramics, ceramic matrix composites, hybrids, advanced and affordable metals, and intermetallics. Continue to transition 2700-degree Fahrenheit ceramic matrix composites for turbine hot section components to industry. Continue to develop high performance and affordable metals for next-generation turbine disk and low cost propulsion, aerostructure and munitions components. Continue development and demonstrate advanced materials and process control to enable complex structural components via additive manufacturing. Initiate establishment of a metallic additive design center. Continue development of low cost metallic turbine engine disks made via powder processing technologies for use in high temperature, aggressive environment. Transition computational and data analytics tools that enable production of affordable, complex shape metal components made via additive manufacturing.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	2.487	2.200	2.142	0.000	2.142

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force				Date: February 2019	
Appropriation/Budget Activity 3600 / 3		R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>		Project (Number/Name) 633946 / <i>Materials Transition</i>	
B. Accomplishments/Planned Programs (\$ in Millions)					
FY 2020 decreased compared to FY 2019 by \$0.058 million. Justification for the decrease is described in the plans above.					
Title: Pervasive and Affordable Metals Technologies					
Description: Develop and demonstrate affordable, novel high temperature powder processing materials/ structures and additive metals technology concepts to enable future defense capabilities air vehicle propulsion and computational prediction models.					
FY 2019 Plans: In FY2019 and prior, this work is performed under multiple efforts and projects within PE 0603112F, Advanced Materials for Weapons Systems.					
FY 2020 Base Plans: Continue to demonstrate affordable metallic turbine engine disks made through powder processing technologies through high temperature, aggressive environment testing. Continue to develop low cost, complex shape metallic component made through additive manufacturing for advanced weapon system component prototypes. Continue to develop computational methodologies that incorporate impact of surface residual stress on ability to extend life and lower life cycle cost of air vehicle propulsion system components.					
FY 2020 OCO Plans: Not Applicable					
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$4.000 million. Funding increased due to realignment and consolidation of Pervasive and Affordable Metals work within PE 0603112F, Advanced Materials for Weapon Systems.					
Accomplishments/Planned Programs Subtotals					
	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
	15.257	13.265	14.278	0.000	14.278
Congressional Add: Program increase - Materials Transition of Metals for Hypersonics					
FY 2018 Accomplishments: Not Applicable					
FY 2019 Plans: Conduct congressional directed efforts.					
Congressional Add: Program increase - Metals Affordability Research					
	0.000	10.000			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603112F / <i>Advanced Materials for Weapon Systems</i>	Project (Number/Name) 633946 / <i>Materials Transition</i>
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	FY 2018	FY 2019
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct congressional directed efforts.		
Congressional Adds Subtotals	0.000	13.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity					R-1 Program Element (Number/Name)							
3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>					PE 0603199F / <i>Sustainment Science and Technology (S&T)</i>							
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	20.724	15.150	16.249	0.000	16.249	16.938	17.731	18.324	18.690	Continuing	Continuing
635351: <i>Technology Sustainment</i>	-	20.724	15.150	16.249	0.000	16.249	16.938	17.731	18.324	18.690	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops and demonstrates mature Air Force Research Laboratory (AFRL) sustainment technologies such as: materials, corrosion, maintenance/repair techniques, state awareness/non-destructive inspection, health management, life prediction, low observable materials and processes, composite materials and logistics for transition into fielded Air Force systems to reduce life cycle sustainment costs and increase readiness. Technologies matured and demonstrated impact affordability and availability of fielded aerospace weapon systems by reducing sustainment costs, extending service life, and maintaining mission readiness and capability. This program develops and demonstrates maintenance, life cycle management, and system/fleet decision making technologies that can be implemented to address operational sustainment issues and could influence future system sustainability decisions via risk reduction to support inclusion into new systems. Studies are conducted to analyze processes and methodologies for application of technologies to address sustainment issues across the force, identifying cross cutting applications for fielded systems, and opportunities for building in sustainability into future applications. This program also develops and demonstrates affordable advanced composites for aircraft structures of fielded and emerging systems. This includes studies, analysis, and tests for application of composites to address sustainment and affordability issues across the force. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)	R-1 Program Element (Number/Name) PE 0603199F I Sustainment Science and Technology (S&T)
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	22.811	15.150	16.249	0.000	16.249
Current President's Budget	20.724	15.150	16.249	0.000	16.249
Total Adjustments	-2.087	0.000	0.000	0.000	0.000
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-0.134	0.000			
• Other Adjustments	-1.953	0.000	0.000	0.000	0.000

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

C. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: System Health Management/Assessment Technologies	4.305	5.171	5.100	0.000	5.100
Description: Develop, demonstrate, and transition state awareness/system health management technologies. Conduct studies and analyses to design sustainability into future applications. The short-term tasks in this area are selected based on warfighter needs identified via a semi-annual, competitive process.					
FY 2019 Plans: Complete development of automated software release capability to assess and maintain system health. Continue development of diagnostic system to assess aircraft wiring and avionics subsystems. Continue development of system to reduce maintenance requirements of carbon monoxide detection system. Continue health assessments capability development for fielded air/space/cyber systems and components. Continue development and demonstration of diagnostic technology to monitor/assess health of airframe/engine, launch vehicle, spacecraft, intercontinental ballistic missiles (ICBMs), and components. These efforts are in Air Force Air, Space, and Cyber mission areas. Continue development of testing systems to assess aircraft electrical subsystems. Initiate new efforts based on competitive selection processes in FY 2018.					
FY 2020 Base Plans:					

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603199F / <i>Sustainment Science and Technology (S&T)</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Complete development of diagnostic system to assess aircraft wiring and avionics subsystems. Complete development of system to reduce maintenance requirements of carbon monoxide detection system. Continue health assessments capability development for fielded air/space/cyber systems and components. Continue development and demonstration of diagnostic technology airframe/engine, launch vehicle, spacecraft, intercontinental ballistic missiles (ICBMs), and components. These efforts are in Air Force Air, Space, and Cyber mission areas. Initiate new efforts based on competitive selection processes in FY 2019.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.071 million. Justification for the decrease is described in the plans above.</p>					
<p>Title: Prevention/Enhanced Maintainability Technologies</p> <p>Description: Develop, demonstrate, and transition maintenance and sustainment technologies to improve component design, maintenance, replacement, and concepts for performance improvement and reduced maintenance burden. The short-term tasks in this effort are selected based on warfighter needs identified via a semi-annual, competitive process.</p> <p>FY 2019 Plans: Complete thermal spray coating process development for engine components. Complete development of an improved method for removal of biofilms from in ground fuel storage systems. Complete improved durability conductive tape and enhanced edge treatment repair development for transition to the B-2. Continue Rapid Repair Requirements materials development for aircraft battle damage repair of advanced fighter aircraft. Continue Advanced Canopy Technology development. Initiate total body non-destructive evaluation system for outer mold line inspection of advanced fighter aircraft. Continue development of materials and processes to reduce maintenance burden on low observable systems. Continue efforts to demonstrate high reliability of repair and maintenance technologies to increase service time between maintenance actions. Continue to develop, demonstrate, and transition maintenance and sustainment technologies to improve component design, maintenance, repair, replacement, and concepts for maintainer training, extending part life, and reduced maintenance burden spanning Air Force Air, Space, and Cyber mission areas. Initiate new efforts based on competitive selection processes in FY 2018.</p> <p>FY 2020 Base Plans:</p>	4.305	5.171	5.896	0.000	5.896

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603199F / <i>Sustainment Science and Technology (S&T)</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
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Complete adaptive gaming concept development for maintainer training. Continue Rapid Repair Requirements materials development for aircraft battle damage repair of advanced fighter aircraft. Continue Advanced Canopy Technology development. Continue total body nondestructive evaluation system for outer mold line inspection of advanced fighter aircraft. Continue development of materials and processes to reduce maintenance burden on low observable systems. Continue efforts to demonstrate high reliability of repair and maintenance technologies to increase service time between maintenance actions. Continue to develop, demonstrate, and transition maintenance and sustainment technologies to improve component design, maintenance, repair, replacement, and concepts for maintainer training, extending part life, and reduced maintenance burden spanning Air Force Air, Space, and Cyber mission areas. Initiate Abrasion Resistance Coating development to protect composite material substrates for low observable systems. Initiate development on a flexible crack-blunting primer. Initiate development on a mid-temp flexible light weight Radiation-absorbent material (RAM) system. Initiate other new efforts based on competitive selection processes in FY 2019.

FY 2020 OCO Plans:
Not Applicable

FY 2019 to FY 2020 Increase/Decrease Statement:
FY 2020 increased compared to FY 2019 by \$0.725 million. Justification for the increase is described in the plans above.

<p>Title: Management/Improved Reliability Technologies</p> <p>Description: Develop, demonstrate, and transition technologies to improve existing and new components, fleet management/ decision-making tools, and supply chain/sustainment infrastructure to decrease downtime and costs, and increase reliability. The short-term tasks in this effort are selected based on warfighter needs identified via a semi-annual, competitive process.</p> <p>FY 2019 Plans: Complete data mining software development to determine asset availability. Continue effort to assess and accurately determine B-2 exhaust liner thermal profile and structural environment, and demonstrate performance of exhaust structures coatings. Continue software development to increase speed and accuracy of solid rocket motor inspections to reduce sustainment costs and improve reliability. Continue development of analysis techniques to extend engine component service life. Continue efforts to develop system fleet management decision-making tools, maintenance/repair data base technologies and techniques, and supply chain/</p>	4.107	4.024	5.253	0.000	5.253
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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force				Date: February 2019						
Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>		R-1 Program Element (Number/Name) PE 0603199F / <i>Sustainment Science and Technology (S&T)</i>								
C. Accomplishments/Planned Programs (\$ in Millions)										
<p>infrastructure approaches to reduce sustainment costs. These efforts span Air Force Air, Space, and Cyber mission areas. Initiate new efforts based on competitive selection processes in FY 2018.</p> <p>FY 2020 Base Plans: Complete effort to assess and accurately determine B-2 exhaust liner thermal profile and structural environment, and demonstrate performance of exhaust structures coatings. Complete software development to increase speed and accuracy of solid rocket motor inspections to reduce sustainment costs and improve reliability. Continue system development to provide prognostic capabilities for avionics components and analysis techniques to extend engine component service life. Continue efforts to develop system fleet management decision-making tools, maintenance/repair data base technologies and techniques, and supply chain/ infrastructure approaches to reduce sustainment costs. These efforts span Air Force Air, Space, and Cyber mission areas. Initiate new efforts based on competitive selection processes in FY 2019.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.229 million. Funding increased due to short-term tasks being selected based on warfighter needs identified via a semi-annual competitive process.</p>						FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Title: Composite Certification</p> <p>Description: Develop, demonstrate and transition reliability-based design of advanced composites for aircraft structures. This includes studies and analysis of processes and methodologies for application of composites to address sustainment and affordability issues across the force.</p> <p>FY 2019 Plans: Continue service life extension demonstration on a legacy fleet aircraft composite part.</p> <p>FY 2020 Base Plans: In FY 2020 Composite Certification efforts were transferred to PE 0603211F, Aerospace Technology Dev/Demo, Project 634920, Flight Vehicle Technology Integration in order to integrate engineering efforts for transition.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>						8.007	0.784	0.000	0.000	0.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603199F / <i>Sustainment Science and Technology (S&T)</i>
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 compared to FY 2019 decreased by \$0.784 million. Funding decreased due composite certification work moved and consolidated under PE 0603211F.					
Accomplishments/Planned Programs Subtotals	20.724	15.150	16.249	0.000	16.249

D. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	46.784	44.968	38.292	0.000	38.292	38.538	40.980	41.079	41.400	Continuing	Continuing
63665A: <i>Advanced Aerospace Sensors Technology</i>	-	28.634	24.992	21.277	0.000	21.277	21.324	21.750	21.970	22.409	Continuing	Continuing
6369DF: <i>Target Attack and Recognition Technology</i>	-	18.150	19.976	17.015	0.000	17.015	17.214	19.230	19.109	18.991	Continuing	Continuing

A. Mission Description and Budget Item Justification

The program develops and demonstrates advanced technologies for electro-optical sensors, radar sensors and electronic counter-countermeasures, and components and algorithms. It also develops and demonstrates radio frequency (RF) and electro-optical (EO) sensors for detecting, locating, and targeting airborne, fixed, and time-critical mobile ground targets obscured by natural or man-made means. This program develops the means to find, fix, target, track, and engage air and ground targets anytime, anywhere, and in any weather. This program has been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	40.978	39.968	41.662	0.000	41.662
Current President's Budget	46.784	44.968	38.292	0.000	38.292
Total Adjustments	5.806	5.000	-3.370	0.000	-3.370
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	7.000	5.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.194	0.000			
• Other Adjustments	0.000	0.000	-3.370	0.000	-3.370

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 63665A: *Advanced Aerospace Sensors Technology*

Congressional Add: *Program Increase*

Congressional Add: *Program increase - sensor integration*

Congressional Add Subtotals for Project: 63665A

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	6.826	0.000
	0.000	5.000
Congressional Add Subtotals for Project: 63665A	6.826	5.000
Congressional Add Totals for all Projects	6.826	5.000

Change Summary Explanation

Decrease in FY 2020 due to realignment of electronic warfare science and technology funding from PE 0603203F, Advanced Aerospace Sensors to PE 0602204F, Aerospace Sensors.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>				Project (Number/Name) 63665A / <i>Advanced Aerospace Sensors Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
63665A: <i>Advanced Aerospace Sensors Technology</i>	-	28.634	24.992	21.277	0.000	21.277	21.324	21.750	21.970	22.409	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project area develops and demonstrates aerospace sensor and processing technologies for intelligence, surveillance, reconnaissance, target, and attack radar applications in both manned and unmanned platforms, including electro-optical sensors and electronic counter-countermeasures for radars. It provides aerospace platforms with the capability to precisely detect, track, and target both airborne (conventional and low radar cross-section) and ground-based, high-value, time-critical targets in adverse clutter and jamming environments. Project activities include developing multi-function radio-frequency systems including radar and electronic warfare technology and the position and timing information to enable distributed sensing. Desired warfighting capabilities include the ability to detect concealed targets in difficult background conditions.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Persistent Sensing in Contested Environment Technologies	2.761	2.412	2.987	0.000	2.987
Description: Develop active radio frequency sensor solutions to use against difficult-to-detect targets in challenging environments, and advanced radio frequency architectures for open and reconfigurable systems. Enable persistent intelligence, surveillance and reconnaissance over wide areas, and detect advanced air and ground targets.					
FY 2019 Plans: Conduct controlled environment ground-based data collections to validate distributed coherent radar proof-of-concept at X and S-bands for synthetic aperture radar.					
FY 2020 Base Plans: Analyze results of ground-based data collections extending models to include more complex platform motion and timing synchronization as a foundation for FY 2022 airborne distributed coherent radar proof-of-concept.					
FY 2020 OCO Plans: Not applicable					
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.575 million. Justification for this increase is described in plans above.					
Title: Passive Radio Frequency Sensing Technologies	4.844	4.523	5.500	0.000	5.500

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 63665A / <i>Advanced Aerospace Sensors Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Description: Develop advanced techniques and prototype passive radio frequency sensors to intercept, collect, locate and track enemy radio frequency sensor systems for intelligence, surveillance and reconnaissance of air and ground targets.</p> <p>FY 2019 Plans: Integrate millimeter-wave hardware and software radio frequency sensor suite for proof-of-concept to intercept, collect, locate and track evolving adversary air and ground sensor systems with evolving agile radio frequency signals of interest.</p> <p>FY 2020 Base Plans: Conduct outdoor range testing of integrated millimeter-wave hardware and software radio frequency sensor suite against calibrated radio frequency signals to validate operating conditions.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.977 million. Justification for this increase is described in plans above.</p>					
<p>Title: Long Range Sensing Technologies</p> <p>Description: Develop radio frequency sensor technology to detect, locate, and identify air and ground targets at long ranges, including those that are low-observable, or use deception or camouflage.</p> <p>FY 2019 Plans: Integrate Passive Radar Illumination Selection Manager hardware and software and conduct data collection on a finite number of radio frequency emitters (cooperative/non-cooperative) and assess the utility of correlated multi-mode operation. Evaluate data collected from experiments that coordinate air and space radio frequency sensors for detection and location of air and ground radio frequency emitters.</p> <p>FY 2020 Base Plans: Conduct additional Passive Radar Illumination Selection Manager data collection by increasing the number of emitters and raise the complexity of the radio frequency waveforms used in order to further test the automated operation of the illumination selection manager hardware/software suite. Conduct additional air and space radio</p>	2.613	2.262	2.903	0.000	2.903

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 63665A / <i>Advanced Aerospace Sensors Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>frequency sensor detection and location of air/ground radio frequency emitters to improve fidelity of multi-mode radar signal processing tools.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.641 million. Justification for this increase is described in plans above.</p>					
<p>Title: Passive Electro-Optical Sensing for Surveillance and Reconnaissance Technologies</p> <p>Description: Advance, demonstrate, and transition innovative imaging and non-imaging optical sensing technologies for surveillance and reconnaissance of airborne and ground-based objects of interest in an anti-access/area denial environment. This effort includes the development of systems, subsystems, and components necessary to yield new capabilities.</p> <p>FY 2019 Plans: Complete focal plane and other component technologies to enhance performance of a staring infrared search and track architecture. Prepare for a flight test of a staring infrared search and track architecture. Continue examination of approaches and technologies to reduce size, weight and power of an infrared search and track system while maintaining operationally relevant performance. Continue improvements in algorithms and software required for target detection and tracking and clutter suppression. Test candidate systems and subsystems in a laboratory environment. Advance and refine engineering trades and system optimization for this novel approach, through modeling and simulation. Continue refinement and prototyping of novel software/hardware combined sensing strategy for turbulence mitigation in passive electro-optical/infrared reconnaissance systems to improve the useful range beyond the current state of the art.</p> <p>FY 2020 Base Plans: Complete fabrication of read-out integrated circuit, focal plane and prototype integrated dewar assembly for the flight infrared search and track system. Conduct flight testing and report performance of both the hardware and detection and tracking algorithms. Procure and integrate dual-band test components for tower collection. Complete dual-band infrared tower collection to analyze imaging improvements with new focal plane array technologies.</p> <p>FY 2020 OCO Plans:</p>	7.397	6.933	5.998	0.000	5.998

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 63665A / <i>Advanced Aerospace Sensors Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Not applicable					
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$0.935 million. Justification for this decrease is described in plans above.					
<i>Title:</i> Laser Radar for Non-Cooperative Identification <i>Description:</i> Advance, demonstrate, and transition innovative laser radar sensing technologies for non-cooperative identification of airborne and ground objects of interest in an anti-access/area denial environment. This effort includes the development of systems, subsystems and components necessary to yield new capabilities. <i>FY 2019 Plans:</i> Establish predictive synthetic aperture laser radar performance model based on measured data and theoretical modeling. Continue development and integration of enhanced components and subsystems. Demonstrate the associated improvement in performance in a laboratory environment. Refine and test holographic aperture laser radar technology under development based on modeling and simulation to enhance spatial resolution beyond the diffraction limit of individual optical apertures. Fabricate, modify, and test critical components and subsystems for a holographic aperture laser radar demonstration in a laboratory environment. Continue sensor automatic target recognition software by applying previous phenomenology research and advanced mathematical concepts. Continue emphasizing long range air-to-air laser radar concepts through modeling and simulation to support system design and analysis of alternatives. Prepare for future technology demonstrations to advance system, subsystem, and component technology readiness levels. <i>FY 2020 Base Plans:</i> Conduct flight test of pathfinder laser for novel 3 dimension shape sensing waveform. Continue development of agile waveform, high power laser. Continue flight testing of synthetic aperture lidar capability with an emphasis on collecting data for processing improvements, for automatic target recognition, and for anchoring modeling and simulation for future performance predictions. Continue flight testing of a vibration sensing system to collect data for an aided target recognition study. <i>FY 2020 OCO Plans:</i> Not applicable <i>FY 2019 to FY 2020 Increase/Decrease Statement:</i>	4.193	3.862	3.889	0.000	3.889

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 63665A / <i>Advanced Aerospace Sensors Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 increased compared to FY 2019 by \$0.027 million. Justification for this increase is described in plans above.					
Accomplishments/Planned Programs Subtotals	21.808	19.992	21.277	0.000	21.277

	FY 2018	FY 2019
Congressional Add: Program Increase <i>FY 2018 Accomplishments:</i> Conducted congressionally directed effort. <i>FY 2019 Plans:</i> Not Applicable	6.826	0.000
Congressional Add: Program increase - sensor integration <i>FY 2018 Accomplishments:</i> Not Applicable <i>FY 2019 Plans:</i> Conduct Congressionally directed efforts	0.000	5.000
Congressional Adds Subtotals	6.826	5.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>				Project (Number/Name) 6369DF / <i>Target Attack and Recognition Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
6369DF: <i>Target Attack and Recognition Technology</i>	-	18.150	19.976	17.015	0.000	17.015	17.214	19.230	19.109	18.991	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project area develops and demonstrates advanced technologies for closed-loop, multi-domain, multi-intelligence sources, multi-platform, multi-sensor automation and autonomy, providing capabilities in battle management, fire control, battlespace awareness and visualization, predictive analytics, target recognition, sensor and information fusion, and sensor / platform asset tasking. This project also conducts advanced investigations to determine solution credibility, in terms of underlying technology and in terms of consistency with future Air Force missions within highly contested environments. This project includes robust techniques to support intelligence, surveillance, and reconnaissance and targeting missions within adverse weather conditions and against adversaries employing deceptive techniques. This project includes development of software-intensive solutions suitable for cloud-based integration and for development/operations-like operational environments. This project develops technology for effective management of online and offline information sources incorporating both constrained and cooperative sensing. In FY 2020, this project was realigned to better reflect technical areas being emphasized such as autonomy, multi-domain and multi-sensor information processing, leverage of machine learning developments and enterprise-level modeling, simulation and analysis.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: Integrated Sensor Targeting Technologies	3.359	3.697	0.000	0.000	0.000
Description: Develop an advanced suite of sensors with automatic target recognition, fusion, and target tracking, all working in concert to provide a high-confidence identification capability.					
FY 2019 Plans: Extend development of multi-intelligence detection for multiple named areas of interest in multiple areas of regard. Conduct laboratory test of task flexibility with payload management and knowledge reasoning with electronic support measure and intelligence, surveillance and reconnaissance. Initiate development of multi-platform resource management aggregate planning capability.					
FY 2020 Base Plans: Starting in FY 2020, this work will be performed under the Advanced Multisource Exploitation effort within Project 6369DF, Target Attack and Recognition Technology.					
FY 2020 OCO Plans: Not applicable					
FY 2019 to FY 2020 Increase/Decrease Statement:					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 6369DF / <i>Target Attack and Recognition Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 decreased compared to FY 2019 by \$3.697 million. Funding decreased due to realignment to Advanced Multisource Exploitation effort within Project 6369DF, Target Attack and Recognition Technology.					
<p>Title: Multi-Sensor Target Recognition</p> <p>Description: Develop and assess multi-sensor automatic target recognition for intelligence, surveillance, reconnaissance, strike, and weapon systems.</p> <p>FY 2019 Plans: Demonstrate flyable, real-time deep learning-based synthetic aperture radar target identification. Conduct large electro-optical data collection/characterization and assessment in conjunction with the National Geospatial-Intelligence Agency. Develop performance model for deep learning synthetic aperture radar target recognition.</p> <p>FY 2020 Base Plans: Starting in FY 2020, this work will be performed under the Advanced Modeling Simulation and Analysis for Multi-Intelligence/Domain Fusion and the Sensing Assignments and Multisource Analytics efforts within Project 6369DF, Target Attack and Recognition Technology.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$8.216 million. Funding decreased due to realignment to Advanced Modeling Simulation and Analysis for Multi-Intelligence/Domain Fusion and Sensing Assignments and Multisource Analytics efforts within Project 6369DF, Target Attack and Recognition Technology.</p>	7.465	8.216	0.000	0.000	0.000
<p>Title: Wide-Angle Continuously-Staring Technologies</p> <p>Description: Develop wide angle, continuous staring, multi-sensor/wavelength sensing and automated exploitation technology to detect, track, and identify targets over large areas at high sensor update rates.</p> <p>FY 2019 Plans: Continue development of stand-off (air and space) and episodic stand-in sensing capabilities for contested and denied environments. Continue to demonstrate tracking, change detection, and image processing capabilities for data representative of contested and denied environments. Collect, process, and catalogue data from advanced wide-angle sensor. Develop feature aided tracking methods for wide angle radio frequency sensors.</p>	7.326	8.063	0.000	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 6369DF / <i>Target Attack and Recognition Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Initiate multi-target tracking, improvement to three-dimensional radar products, and surrogate radar sensing capability.</p> <p>FY 2020 Base Plans: Starting in FY 2020, this work will be performed under the Advanced Modeling, Simulation and Analysis for Multi-Intelligence/Domain Fusion and the Sensing Assignments and Multisource Analytics efforts within Project 6369DF, Target Attack and Recognition Technology.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$8.063 million. Funding decreased due to realignment to Advanced Modeling, Simulation and Analysis for Multi-Intelligence/Domain Fusion and Sensing Assignments and Multisource Analytics efforts within Project 6369DF, Target Attack and Recognition Technology.</p>					
<p>Title: Advanced Multi-Source Exploitation</p> <p>Description: Demonstrate multi-source behavioral and physical knowledge generation algorithms on operational data sets for specific customers and evaluate the performance of the algorithms with respect to contested environment scenarios. Investigate methods for reducing the size, weight and power footprint of information fusion techniques to enable technology transition. Automate algorithm components to increase warfighter efficiency by reducing human-in-the-loop timeframes. Develop intelligent reasoning capabilities that inform operators with respect to information requirements to improve/enable mission success, for example, autonomously recommend additional data collection geometries/scenarios to enhance fusion for synthesis performance.</p> <p>FY 2019 Plans: For FY 2019 and prior, this work is performed under the Integrated Sensor Targeting Technologies effort within Project 6369DF, Target Attack and Recognition Technology.</p> <p>FY 2020 Base Plans: Mature and transition technology to three customers: Air Combat Command Combat Identification, Air Force Distributed Common Ground System, and Space. Candidate technologies include decision/feature-level</p>	0.000	0.000	3.655	0.000	3.655

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 6369DF / <i>Target Attack and Recognition Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>fusion for stationary target classification given multi-sensor imagery, and deep/machine learning detect/track/identification techniques.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$3.655 million. Funding increased due to realignment from Integrated Sensor Targeting Technologies effort within Project 6369DF, Target Attack and Recognition Technology to better reflect technical areas being emphasized such as autonomy, multi-domain and multi-sensor information processing, leverage of machine learning developments and enterprise-level modeling, simulation and analysis.</p>					
<p>Title: Advanced Modeling, Simulation and Analysis for Multi-Intelligence/Domain Fusion</p> <p>Description: This advanced research will concentrate on leveraging existing modeling, simulation and analysis tactics, techniques and procedures as well as advancing the multi int/domain fusion of information to understand with greater fidelity how current and future generations of intelligence, surveillance and reconnaissance air, space and cyber sensing can be most effectively applied to the battlespace.</p> <p>FY 2019 Plans: For FY 2019 and prior, this work is performed under the Multi-Sensor Target Recognition and the Wide-Angle Continuously-Staring Technologies efforts within Project 6369DF, Target Attack and Recognition Technology.</p> <p>FY 2020 Base Plans: Advanced research investments will be made in the following: 1) increased fidelity and integration of air, space, cyber, and fusion performance models into modeling and simulation capabilities for phase 0 and phase 1/2 analysis, 2) specific analysis support to the Air Force Research Laboratory Enterprise modeling, simulation and analysis 3) Integration of distributed small satellites, cyber physical sensing, electronic warfare, and passive and multi-static radio frequency capabilities into the modeling, simulation and analysis baseline, and 4) increase focus on synthetic data generation as an alternative test method to measured data.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	0.000	0.000	4.815	0.000	4.815

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 6369DF / <i>Target Attack and Recognition Technology</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2020 increased compared to FY 2019 by \$4.815 million. Funding increased due to realignment from Multi-Sensor Target Recognition and Wide-Angle Continuously-Staring Technologies efforts within Project 6369DF, Target Attack and Recognition Technology to better reflect technical areas being emphasized such as autonomy, multi-domain and multi-sensor information processing, leverage of machine learning developments and enterprise-level modeling, simulation and analysis.					
<p>Title: Sensing Assignments and Multisource Analytics</p> <p>Description: Develop advanced techniques for multi-domain closed-loop sensing that apply predictive analytics to available information, inferring candidate course-of-action hypotheses and recommending confirmatory / refutative sensing tasks.</p> <p>FY 2019 Plans: For FY 2019 and prior, this work is performed under the Multi-Sensor Target Recognition and the Wide-Angle Continuously-Staring Technologies efforts within Project 6369DF, Target Attack and Recognition Technology.</p> <p>FY 2020 Base Plans: Develop algorithms to generate and modify rule-based representations of adversary courses of action, and conduct laboratory tests to assess utility and streamline performance. Develop advanced representations of available sensing and platform assets, and develop techniques to correctly and automatically convert high-level sensing requests into detailed asset plans.</p> <p>FY 2020 OCO Plans: Not applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$8.545 million. Funding increased due to realignment from Multi-Sensor Target Recognition and Wide-Angle Continuously-Staring Technologies efforts within Project 6369DF, Target Attack and Recognition Technology to better reflect technical areas being emphasized such as autonomy, multi-domain and multi-sensor information processing, leverage of machine learning developments and enterprise-level modeling, simulation and analysis.</p>	0.000	0.000	8.545	0.000	8.545
Accomplishments/Planned Programs Subtotals	18.150	19.976	17.015	0.000	17.015

C. Other Program Funding Summary (\$ in Millions)
N/A

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603203F / <i>Advanced Aerospace Sensors</i>	Project (Number/Name) 6369DF / <i>Target Attack and Recognition Technology</i>

C. Other Program Funding Summary (\$ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force / BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603211F / <i>Aerospace Technology Dev/Demo</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	103.123	126.002	102.949	0.000	102.949	79.994	84.998	86.480	88.211	Continuing	Continuing
634920: <i>Flight Vehicle Tech Integration</i>	-	20.336	31.679	31.969	0.000	31.969	33.618	34.844	35.312	36.019	Continuing	Continuing
634926: <i>High Speed/Hypersonic Intgr and Demo</i>	-	68.376	78.324	48.959	0.000	48.959	21.592	22.031	22.476	22.926	Continuing	Continuing
634927: <i>Flight Systems Control</i>	-	14.411	15.999	22.021	0.000	22.021	24.784	28.123	28.692	29.266	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program supports Department of Defense (DoD) priorities for demonstrations in hypersonics and manned/unmanned systems, respectively. This effort integrates and demonstrates advanced flight vehicle technologies that improve the performance and supportability of existing and future aerospace vehicles. System level integration brings together aerospace vehicle technologies along with avionics, propulsion, and weapon systems for demonstration in a near-realistic operational environment. Integration and technology demonstrations reduce the risk and time required to transition technologies into operational aircraft. Projects in this program have been coordinated through the DoD Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)	R-1 Program Element (Number/Name) PE 0603211F I Aerospace Technology Dev/Demo
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	115.966	121.002	105.411	0.000	105.411
Current President's Budget	103.123	126.002	102.949	0.000	102.949
Total Adjustments	-12.843	5.000	-2.462	0.000	-2.462
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	5.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-0.134	0.000			
• SBIR/STTR Transfer	-1.018	0.000			
• Other Adjustments	-11.691	0.000	-2.462	0.000	-2.462

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 634920: *Flight Vehicle Tech Integration*

Congressional Add: *Program increase - aircraft winglets and drag reduction devices*

Congressional Add Subtotals for Project: 634920

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	0.000	5.000
	0.000	5.000
	0.000	5.000

Change Summary Explanation

Decrease in FY 2018 of \$11.691 million in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

Decrease in FY 2020 of \$2.462 million is due to changes in Air Force Science and Technology advanced technology demonstrations.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603211F / Aerospace Technology Dev/ Demo				Project (Number/Name) 634920 / Flight Vehicle Tech Integration			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
634920: <i>Flight Vehicle Tech Integration</i>	-	20.336	31.679	31.969	0.000	31.969	33.618	34.844	35.312	36.019	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project demonstrates advanced aerospace vehicle technologies. Aerospace Vehicle Technology Integration efforts are accomplished through integration of various technologies to include avionics, advanced propulsion, and weapon systems for demonstration in near-realistic operational environments. Advanced Aerospace Structures Technologies are demonstrated to enhance the capability of current and future aerospace vehicles.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Aerospace Vehicle Technology Integration</p> <p>Description: Develop, simulate, and demonstrate integrated technologies to improve the performance of aerospace platform capabilities.</p> <p>FY 2019 Plans: Continue next generation mobility vehicle technology experiments. Initiate integrated full flow path demonstration of a medium bypass embedded engine for next generation mobility. Initiate the flight demonstration of a low cost unmanned aerospace systems (UAS) capable of interoperations with different UAS assets. Initiate propulsion integrations component validation tests for Air Superiority 2030 requirements.</p> <p>FY 2020 Plans: Continue integrated full flow path demonstration of a medium bypass embedded engine for next generation mobility. Continue the flight demonstration of a low cost unmanned aerospace systems capable of interoperations with different UAS assets; completing a sensor extension variant in FY 2020 and initiating an off-board weapons station variant. Continue propulsion integration component validation tests for Air Superiority 2030 requirements. Initiate flight demonstrations of practical laminar flow for swept wing aircraft designs.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$4.710 million. Funding increased due to additional emphasis in the flight demonstrations of low cost unmanned aerospace systems.</p>	10.687	10.342	15.052
<p>Title: Advanced Aerospace Structure Technologies</p> <p>Description: Develop and demonstrate affordable, lightweight, adaptive, and multifunctional structural concepts integrated into aerospace systems.</p>	9.649	16.337	16.917

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603211F / <i>Aerospace Technology Dev/ Demo</i>	Project (Number/Name) 634920 / <i>Flight Vehicle Tech Integration</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p><i>FY 2019 Plans:</i> Continue low cost airframe design and manufacturing demonstrations. Continue low cost attributable aircraft flight demonstration analysis and support. Initiate structural life extension demonstration of legacy fleet metallic structures.</p> <p><i>FY 2020 Plans:</i> Continue low cost airframe design and manufacturing demonstrations: completing rapid manufacturing demonstrations of airframe components in FY 2020, and initiating fully automated manufacturing demonstrations of large airframe structures. Complete low cost attributable aircraft flight demonstration analysis and support. Continue structural life extension demonstration of legacy fleet metallic structures. Initiate validation tests of life extension and durability methods for legacy fleet composite structures in support of aircraft Service Life Extension programs.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.580 million. Justification for the increase is described in the plans above.</p>			
Accomplishments/Planned Programs Subtotals	20.336	26.679	31.969

	FY 2018	FY 2019
<i>Congressional Add:</i> Program increase - aircraft winglets and drag reduction devices	0.000	5.000
<i>FY 2018 Accomplishments:</i> Not Applicable		
<i>FY 2019 Plans:</i> Conduct Congressionally directed efforts		
Congressional Adds Subtotals	0.000	5.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603211F / Aerospace Technology Dev/ Demo	Project (Number/Name) 634926 / High Speed/Hypersonic Intgr and Demo
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
634926: High Speed/Hypersonic Intgr and Demo	-	68.376	78.324	48.959	0.000	48.959	21.592	22.031	22.476	22.926	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops, integrates and demonstrates, via simulations, ground, and flight tests, advanced flight vehicle technologies that improve the performance and supportability of future high speed/hypersonic vehicles. System level integration brings together air vehicle technologies with avionics, propulsion, and warheads and other aerospace subsystems for demonstration in a near-realistic operational environment. Integration and technology demonstrations reduce the risk and time required to transition technologies into operational systems.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: High Speed/Hypersonic Vehicle Technologies	68.376	78.324	48.959
Description: Develop, simulate, and demonstrate integrated vehicle technologies to enable and improve the performance of future high-speed and hypersonic systems.			
FY 2019 Plans: Continue accelerated development and demonstration of tactically-relevant long-range high-speed strike technologies including ground and flight demonstrations needed. Initiate and complete Hypersonic Air-breathing Weapon Concept (HAWC) and Tactical Boost Glide (TBG) integration, assembly, test, and checkout. Initiate flight test activities for both HAWC and TBG.			
FY 2020 Plans: Continue development and demonstration of tactically-relevant long-range high-speed strike technologies including ground and flight demonstrations needed. Complete Hypersonic Air-breathing Weapon Concept (HAWC) and Tactical Boost Glide (TBG) integration, assembly, test, and checkout. Continue some flight test activities for both HAWC and TBG.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$29.365 million. Funding decreased due to High Speed Strike Weapon (HSSW) work transitioning to flight test.			
Accomplishments/Planned Programs Subtotals	68.376	78.324	48.959

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603211F / <i>Aerospace Technology Dev/ Demo</i>	Project (Number/Name) 634926 / <i>High Speed/Hypersonic Intgr and Demo</i>

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603211F / <i>Aerospace Technology Dev/Demo</i>				Project (Number/Name) 634927 / <i>Flight Systems Control</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
634927: <i>Flight Systems Control</i>	-	14.411	15.999	22.021	0.000	22.021	24.784	28.123	28.692	29.266	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program integrates and demonstrates advanced control technologies that improve the performance, reliability, safety, and survivability of existing and future, manned and unmanned, aerospace systems. Enhanced capabilities are enabled by control, automation, and system level integration of subsystems and systems such as propulsion, airframes, avionics, power & thermal management, weapons, communications, and operator interfaces. Modeling and simulation, integration, and technology demonstrations in a near-operational environment reduce the risk and time required to transition technologies into existing and future aerospace systems.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Autonomous Systems Control	14.411	15.999	22.021
Description: Develop, simulate, and demonstrate advanced automation and control-enabled capabilities for manned or unmanned aerospace platforms. Develop, simulate, and demonstrate autonomous flight controls for safe flight and cooperative operations between manned and remotely piloted air platforms.			
FY 2019 Plans: Continue development and demonstration of technologies for situational awareness, autonomous control, and survivability for unmanned systems and manned platforms. Continue demonstration of autonomous and safe airspace interoperability for manned and remotely piloted aircraft systems. Continue development and demonstration of airborne control of teams of unmanned aircraft. Continue development and demonstration of reduced crew operations of future mobility aircraft. Continue development of unmanned sense-and-avoid technologies for ground and air operations. Continue development of technologies to reduce risk for transition of collision avoidance technologies to 4th and 5th generation aircraft. Continue development of foundational autonomy for unmanned systems and spiral demonstrations of capability.			
FY 2020 Plans: Continue development and demonstration of technologies for situational awareness, autonomous control, and survivability for unmanned systems and manned platforms. Incorporate autonomous and safe airspace interoperability for manned and remotely piloted aircraft systems, airborne control of teams of unmanned aircraft, and unmanned sense-and-avoid technologies for ground and air operations to the autonomy spiral demonstrations. Complete development and demonstration of reduced crew operations of future mobility aircraft. Continue development of technologies to reduce risk for transition of collision avoidance technologies to 4th and 5th-gen aircraft. Continue development of foundational autonomy for unmanned systems and spiral demonstrations of capability, including safe airspace interoperability and sense and avoid for air and ground operations. Initiated spiral autonomy			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603211F / <i>Aerospace Technology Dev/ Demo</i>	Project (Number/Name) 634927 / <i>Flight Systems Control</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
demonstration of manned-unmanned teaming capability incorporating the above technology transitions, including pilot-directed autonomous control.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$6.022 million. Funding increased due to additional focus on rapid development and demonstration of autonomy for manned-unmanned teaming.			
Accomplishments/Planned Programs Subtotals	14.411	15.999	22.021

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	122.217	148.418	113.973	0.000	113.973	115.142	114.123	117.106	120.013	Continuing	Continuing
632480: <i>Aerospace Fuels</i>	-	2.436	2.340	2.386	0.000	2.386	2.434	2.483	2.532	2.583	Continuing	Continuing
633035: <i>Aerospace Power Technology</i>	-	19.204	38.954	24.670	0.000	24.670	22.375	18.492	18.866	19.243	Continuing	Continuing
634921: <i>Aircraft Propulsion Subsystems Int</i>	-	16.341	18.058	18.016	0.000	18.016	18.295	18.853	19.362	19.851	Continuing	Continuing
634922: <i>Space & Missile Rocket Propulsion</i>	-	28.177	40.220	28.256	0.000	28.256	29.686	30.584	31.403	32.199	Continuing	Continuing
635098: <i>Advanced Aerospace Propulsion</i>	-	41.256	20.194	18.814	0.000	18.814	20.169	20.889	21.532	22.158	Continuing	Continuing
63681B: <i>Advanced Turbine Engine Gas Generator</i>	-	14.803	28.652	21.831	0.000	21.831	22.183	22.822	23.411	23.979	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops and demonstrates technologies to achieve enabling and revolutionary advances in turbine, advanced-cycle, rocket, and space propulsion as well as electrical power, thermal management, and fuels. The program has six projects, each focusing on technologies with a high potential to enhance the performance of existing and future Air Force weapon systems. The Aerospace Fuels project develops and demonstrates improved hydrocarbon fuels and advanced propulsion systems, including those for air-breathing, high-speed/hypersonic flight. The Aerospace Power Technology project develops and demonstrates adaptive power and thermal management components, controls, and systems for high-power payloads and aircraft as part of energy-optimized aircraft development. The Aircraft Propulsion Subsystems Integration project develops demonstrator engines by integrating the engine cores demonstrated in the Advanced Turbine Engine Gas Generator project with low-pressure components. The Space and Missile Rocket Propulsion project develops and demonstrates innovative rocket propulsion technologies, propellants, and manufacturing techniques. The Advanced Aerospace Propulsion project develops the scramjet propulsion cycle to a technology readiness level appropriate for in-flight demonstration and for full integration with other engine cycles (including turbine and rocket based). The Advanced Turbine Engine Gas Generator project develops and demonstrates core turbine engine technologies for current and future aircraft propulsion systems.

Portions of the Aerospace Fuels, Aircraft Propulsion Subsystems Integration, and Advanced Turbine Gas Generator projects support adaptive cycle technology demonstrations, which develop component technology for an adaptive cycle engine architecture that provides optimized performance, fuel efficiency, and durability for widely varying mission needs.

Projects in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>
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This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	104.499	115.462	115.610	0.000	115.610
Current President's Budget	122.217	148.418	113.973	0.000	113.973
Total Adjustments	17.718	32.956	-1.637	0.000	-1.637
• Congressional General Reductions	-0.028	-0.044			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	18.500	33.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	3.342	0.000			
• SBIR/STTR Transfer	-4.096	0.000			
• Other Adjustments	0.000	0.000	-1.637	0.000	-1.637

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 633035: Aerospace Power Technology

Congressional Add: *Program increase - silicon carbide research*

Congressional Add Subtotals for Project: 633035

Project: 634922: Space & Missile Rocket Propulsion

Congressional Add: *Program increase*

Congressional Add: *Program increase - chemical apogee engines*

Congressional Add: *Program increase - upper stage engine maturation*

	FY 2018	FY 2019
	10.634	15.000
	10.634	15.000
	7.250	0.000
	0.000	2.500
	0.000	8.500

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>
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Congressional Add Details (\$ in Millions, and Includes General Reductions)

	FY 2018	FY 2019
Congressional Add Subtotals for Project: 634922	7.250	11.000
Project: 63681B: <i>Advanced Turbine Engine Gas Generator</i>		
Congressional Add: <i>Program increase - advanced turbine engine gas generator</i>	0.000	7.000
Congressional Add Subtotals for Project: 63681B	0.000	7.000
Congressional Add Totals for all Projects	17.884	33.000

Change Summary Explanation

Increase in FY 2018 of \$3.342 million is due to a reprogramming action for High Speed Strike Weapon Technology Maturation efforts.

Decrease in FY 2020 of \$1.637 million is due to the realignment of funds for Air Force Science and Technology demonstrations.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>				Project (Number/Name) 632480 / <i>Aerospace Fuels</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
632480: <i>Aerospace Fuels</i>	-	2.436	2.340	2.386	0.000	2.386	2.434	2.483	2.532	2.583	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project evaluates and demonstrates improved hydrocarbon fuels, unique special application fuels, alternate fuels and advanced, novel aerospace propulsion technologies for Air Force applications, including high-speed and hypersonic flight and technologies to increase turbine engine operational reliability, durability, mission flexibility, and performance, while reducing weight, fuel consumption, and cost of ownership. The advanced fuel emphasis is on demonstrating new thermally stable, high-heat sink, and controlled chemically reacting fuels for a conventional turbine engine, turbine-based combined cycle engines, and other advanced propulsion systems. The project also evaluates and demonstrates fuel system components that minimize cost, reduce maintenance, and improve performance of future aerospace systems. The advanced propulsion emphasis is on demonstrating concepts for combined cycle, ramjet, and scramjet engines. A portion of this project supports the demonstration of adaptive cycle technologies. This project develops component technology for an adaptive cycle engine architecture that provides optimized performance, fuel efficiency, and durability for widely varying mission needs.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Fuel-Related Thermal Management</p> <p>Description: Demonstrate thermally stable fuels and fuel system hardware concepts to enhance cooling capacity (performance), minimize fuel coking, and reduce fuel system maintenance.</p> <p>FY 2019 Plans: Continue investigation of fuel heat sink approaches for thermal management of adaptive engines, including on-board fuel deoxygenation.</p> <p>FY 2020 Plans: Continue investigation of fuel heat sink approaches for thermal management of adaptive engines, such as on-board fuel deoxygenation. Initiate investigation of heat exchangers including additive manufactured units. Initiate the development of integrated test rigs to tests these approaches and assess efficiency of these approaches.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 funds increased by \$0.046 million compared to FY 2019. Justification for the increase is described in the plans above.</p>	0.713	0.685	0.731
<p>Title: Gas Turbine Combustion, Emissions, and Performance</p> <p>Description: Develop and demonstrate efficacy of low-cost, environmentally friendly fuel approaches to assess and reduce soot/particulate emissions from gas turbine engines.</p> <p>FY 2019 Plans:</p>	0.647	0.621	0.621

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 632480 / <i>Aerospace Fuels</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Continue development of augmentor combustor/simulator to determine fuel effects on augmentor operability under realistic conditions.</p> <p>FY 2020 Plans: Continue development of augmentor combustor/simulator to determine fuel effects on augmentor operability under realistic conditions. Initiate study of fuel temperature limitations and use data to validate models.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not Applicable</p>				
<p>Title: Fuel Logistics</p> <p>Description: Identify, develop, and demonstrate low-cost approaches to reducing the fuel logistics footprint for the Air Force.</p> <p>FY 2019 Plans: Initiate development of fuel composition in-situ sensors to ensure thermal stability throughout platform mission. Initiate development of fuel sensors and mitigation products to detect and mitigate fuel bio-contamination.</p> <p>FY 2020 Plans: Continue development of fuel composition in-situ sensors to ensure thermal stability throughout platform mission. Continue development of fuel sensors and mitigation products to detect and mitigate fuel bio-contamination.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not Applicable</p>		0.860	0.827	0.827
<p>Title: Alternative Jet Fuels</p> <p>Description: Characterize and demonstrate the use of alternative hydrocarbon jet fuel to comply with Air Force certifications and standards for jet fuels.</p> <p>FY 2019 Plans: Continue development of generic alternative fuel specification annexes for commercial jet fuels used by Air Force.</p> <p>FY 2020 Plans: Complete development of generic alternative fuel specification annexes for commercial jet fuels used by Air Force.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not Applicable</p>		0.216	0.207	0.207
Accomplishments/Planned Programs Subtotals		2.436	2.340	2.386

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 632480 / <i>Aerospace Fuels</i>
C. Other Program Funding Summary (\$ in Millions) N/A		
Remarks		
D. Acquisition Strategy N/A		
E. Performance Metrics Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.		

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>				Project (Number/Name) 633035 / <i>Aerospace Power Technology</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
633035: <i>Aerospace Power Technology</i>	-	19.204	38.954	24.670	0.000	24.670	22.375	18.492	18.866	19.243	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates system and subsystem integration to include adaptive architectures, actuation, electrical power, thermal management, and distribution for aerospace applications. This project develops and demonstrates the components, controls and systems required to satisfy the operational needs of current and future aircraft and enables the use of future high-power payloads. This technology enhances reliability and survivability, and reduces vulnerability, weight, and life cycle costs of air platforms. The electrical power system components developed are projected to provide a two-fold to five-fold improvement in aircraft reliability and maintainability, and a reduction in power system weight. This project is integrated into energy optimized aircraft efforts and power and thermal programs.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: High Power Aircraft Subsystem Technologies	8.570	23.954	24.670
Description: Develop and demonstrate integrated architecture, controls and components for power generation, conditioning, and distribution; energy storage components; and thermal management and subsystem technologies for integration into high power aircraft.			
FY 2019 Plans: Continue development and demonstration of system and component electrical power, electro-mechanical, and thermal technologies for high-power aircraft. Continue development of actuation technology for applications with power, volume, and thermal limitations. Continue the development of hybrid-cycle power and thermal management system. Continue development of advanced power generation and distribution system. Continue development and demonstration of integrated, adaptive megawatt-class tactical aircraft power and thermal capability. Continue development and demonstration of megawatt class architecture, controls and integration. Continue development and demonstration of robust electrical power systems for megawatt applications. Continue development and demonstration of thermal management systems for megawatt applications. Continue development and demonstration of solid state electrical distribution technology for megawatt applications.			
FY 2020 Plans: Continue development and demonstration of system and component electrical power, electro-mechanical, and thermal technologies for high-power aircraft. Complete development of actuation technology for applications with power, volume, and thermal limitations. Continue the development of hybrid-cycle power and thermal management system. Continue development of advanced power generation and distribution system. Continue development and demonstration of integrated, adaptive megawatt-class tactical aircraft power and thermal capability. Continue development and demonstration of megawatt class architecture, controls and integration. Continue development and demonstration of robust electrical power systems for megawatt applications.			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 633035 / <i>Aerospace Power Technology</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Continue development and demonstration of thermal management systems for megawatt applications. Continue development and demonstration of solid state electrical distribution technology for megawatt applications.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.716 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	8.570	23.954	24.670

	FY 2018	FY 2019
<i>Congressional Add:</i> Program increase - silicon carbide research	10.634	15.000
<i>FY 2018 Accomplishments:</i> Conducted Congressionally directed efforts		
<i>FY 2019 Plans:</i> Conduct Congressionally directed efforts		
Congressional Adds Subtotals	10.634	15.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>				Project (Number/Name) 634921 / <i>Aircraft Propulsion Subsystems Int</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
634921: <i>Aircraft Propulsion Subsystems Int</i>	-	16.341	18.058	18.016	0.000	18.016	18.295	18.853	19.362	19.851	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates technology to increase turbine engine operational reliability, durability, mission flexibility, and performance while reducing weight, fuel consumption, and cost of ownership. The Aircraft Propulsion Subsystems Integration (APSI) project includes demonstrator engines for manned systems and efficient small-scale propulsion for remotely piloted aircraft and cruise missile applications. The demonstrator engines integrate the core (high- pressure spool) technology developed under the Versatile Affordable Advanced Turbine Engines (VAATE) project with the engine (low-pressure spool) technology such as fans, turbines, engine controls, mechanical systems, exhaust nozzles, and augmentors. Additionally, this project includes activities to improve propulsion safety and readiness. This project also focuses on integration of inlets, nozzles, engine-to-airframe compatibility, and power and thermal management subsystems technologies. The APSI project provides aircraft with potential for longer range and higher cruise speeds with lower specific fuel consumption, surge power for successful engagements, high sortie rates with reduced maintenance, reduced life cycle cost, and improved survivability, resulting in increased mission effectiveness. Technologies developed are applicable to sustained high-speed vehicles and responsive space launch. The Aircraft Propulsion Subsystems Integration project is focused on improving propulsion capabilities while at the same time reducing the cost of ownership. Anticipated technology advances include turbine engine improvements providing approximately twice the range for a sustained supersonic combat aircraft, doubling the time on station with ten times the power output for surveillance aircraft and propulsion for a high speed supersonic missile with double the range for time sensitive targets. A portion of this project supports the demonstration of adaptive cycle technologies, which develop component technology for an adaptive cycle engine architecture that provides optimized performance, fuel efficiency, high power extraction, integrated thermal management, and durability for widely varying mission needs.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Missile/Remotely Piloted Aircraft Engine Performance	9.724	10.746	10.674
Description: Design, fabricate, and test component technologies for limited-life engines to improve the performance, durability, and affordability of missile and remotely piloted aircraft engines.			
FY 2019 Plans: Complete detailed design of and Critical Design Review (CDR) of a medium-scale efficient core demonstrator. Initiate risk reduction component testing of a medium-scale efficient core demonstrator. Continue risk reduction testing of components for 200lb thrust and 650lb thrust engines. Complete CDR of 200lb thrust engine. Complete testing of 650lb engine. Complete CDR of durability test utilizing small scale cruise missile engine to validate advanced design and life prediction tools for medium and large engine applications. Continue the development of derivative supersonic turbojet engines for missile and high speed			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 634921 / <i>Aircraft Propulsion Subsystems Int</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>accelerators. Continue design of advanced turbine based accelerator with reusable hypersonics applications. Continue vehicle and propulsion system integration analysis.</p> <p>FY 2020 Plans: Continue risk reduction component testing of a medium-scale efficient core demonstrator. Continue risk reduction testing of components for small expendable turbojet/turbofans (100-900 lbs class). Initiate and complete conceptual and detailed design of a medium-scale high power, high efficiency turboprop. Initiate risk reduction component rig testing and initiate fabrication of components in preparation for engine testing for this turboprop. Initiate and complete conceptual design of a high efficiency medium-scale embedded propulsion concept. Continue development of derivative supersonic turbojet engines for missile and high speed accelerators. Complete design and review of advanced turbine based accelerator with reusable high speed applications. Complete vehicle and propulsion system integration analysis.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.072 million. Justification for the decrease is described in the plans above.</p>				
<p>Title: Adaptive Turbine Engine Technologies</p> <p>Description: Design, fabricate, and demonstrate performance, durability, and operability technologies to mature adaptive turbine engine technologies.</p> <p>FY 2019 Plans: Continue to provide subject matter expert support to Adaptive Engine Transition Program. Complete fabrication of components for integrated power and thermal management engine demonstrator. Continue hardware fabrication for an adaptive engine for utilization as an integrated power and thermal management engine demonstrator.</p> <p>FY 2020 Plans: Continue to provide subject matter expert support to Adaptive Engine Transition Program. Complete hardware fabrication for an adaptive engine for utilization as an integrated power and thermal management engine demonstrator. Initiate and complete conceptual design review of adaptive engine core technologies and initiate technology rig tests to decrease risk in core technology testing. Initiate detailed design, fabrication and testing of component technology rig for an adaptive core demonstrator. Initiate conceptual design of fully adaptive architectures and mature critical technologies for future weapon systems.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.030 million. Justification for the increase is described in the plans above.</p>		6.617	7.312	7.342
Accomplishments/Planned Programs Subtotals		16.341	18.058	18.016

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 634921 / <i>Aircraft Propulsion Subsystems Int</i>

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>				Project (Number/Name) 634922 / <i>Space & Missile Rocket Propulsion</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
634922: <i>Space & Missile Rocket Propulsion</i>	-	28.177	40.220	28.256	0.000	28.256	29.686	30.584	31.403	32.199	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates advanced and innovative low-cost rocket turbo-machinery and components, and low-cost space launch propulsion technologies. Additionally, this project develops technologies for the sustainment of strategic systems (including solid rocket motor boosters and missile propulsion, post boost control, and aging and surveillance efforts) and tactical rockets. Characteristics such as environmental acceptability, affordability, reliability, responsiveness, reduced weight, and reduced operation and launch costs are emphasized. Increased life and performance of propulsion systems are key goals. Technology areas investigated include ground demonstrations of compact, lightweight, advanced propulsion technologies, higher efficiency energy conversion systems (derived from an improved understanding of combustion fundamentals), and high-energy propellants. Technological advances in this project could improve the performance of expendable payload capabilities by approximately twenty to fifty percent and reduce launch, operations, and support costs by approximately thirty percent. Responsiveness and operability of propulsion systems will be enhanced for reusable launch systems. Aging and surveillance thrusts for solid rocket motors could reduce lifetime prediction uncertainties for individual motors by fifty percent, enabling motor replacement for cause. The efforts in this project contribute to the sustainment of the rocket propulsion industry, providing rocket propulsion technology for the entire Department of Defense (DoD) and National Aeronautics and Space Administration (NASA). The efforts in this project are part of the Rocket Propulsion 21 (RP21) program. The efforts in this project are reviewed by a DoD level steering committee annually for relevance to DoD missions and achievement of technical goals defined by the RP21 program.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Liquid Rocket Propulsion Technologies	15.204	19.285	15.258
Description: Develop liquid rocket propulsion technology for current and future space launch vehicles.			
FY 2019 Plans: Continue study for next generation liquid propulsion technology demonstration effort focused on modularity and cost reduction. Initiate testing of hydrocarbon engines component.			
FY 2020 Plans: Complete study for next generation liquid propulsion technology demonstration effort focused on modularity and cost reduction. Complete testing of hydrocarbon engine components. Initiate modular engine feasibility demonstration.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$4.027 million. Funding decreased due to completion of hydrocarbon boost technology demonstration effort.			
Title: On-Orbit Propulsion Technologies	1.198	1.753	3.391

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 634922 / <i>Space & Missile Rocket Propulsion</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Description: Develop solar electric, electric, and monopropellant propulsion technologies for existing and future satellites, upper stages, orbit transfer vehicles, and satellite maneuvering.</p> <p>FY 2019 Plans: Continue to develop and transition experimental, modeling and simulation, and theoretical efforts geared towards advanced thruster development with additional emphasis on understanding thrust scale-up. Continue to extend capability to study next generation of hypergolic fuels, including propellant characterization, drop-in testing, and lab-scale thruster demonstration. Continue analysis and development of multi mode propulsion opportunities to combine high efficiency and high thrust capabilities on a common propellant. Initiate thrust scale-up effort for advanced non-toxic mono-propellant thrusters.</p> <p>FY 2020 Plans: Continue to develop and transition experimental, modeling and simulation, and theoretical efforts geared towards advanced thruster development with additional emphasis on understanding thrust scale-up. Continue to extend capability to study next generation of hypergolic fuels, including propellant characterization, drop-in testing, and lab-scale thruster demonstration. Continue analysis and development of multi-mode propulsion opportunities to combine high efficiency and high thrust capabilities on a common propellant. Continue thrust scale-up effort for advanced non-toxic mono-propellant thrusters. Initiate electric propulsion thruster effort utilizing advanced non-toxic mono-propellant.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.638 million. Funding increased due to initiation of electric propulsion thruster effort utilizing advanced non-toxic mono-propellant.</p>			
<p>Title: Ballistic Missile Technologies</p> <p>Description: Develop and demonstrate missile propulsion and post-boost control systems technologies for ballistic missiles.</p> <p>FY 2019 Plans: Complete technology demonstration effort on advanced missile case, insulation, and nozzle technologies and validation of physics-based modeling, simulation, and analysis tools for ballistic and tactical missile solid rocket motors. Continue technology maturation and demonstration efforts for post-boost technologies and tactical missile technologies.</p> <p>FY 2020 Plans: Continue technology maturation and demonstration efforts for post-boost technologies and tactical missile technologies. Initiate motor component modeling & simulation tool development efforts geared towards reducing cost and schedule of new developments.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	1.936	4.676	5.934

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 634922 / <i>Space & Missile Rocket Propulsion</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$1.258 million. Funding increased due to initiation of modeling & simulation tool development efforts.				
Title: Strategic System Motor Surveillance		2.589	3.506	3.673
Description: Develop and demonstrate aging and surveillance technologies for strategic systems to reduce lifetime prediction uncertainty for individual motors, enabling motor replacement for cause.				
FY 2019 Plans: Continue to apply next generation of chemical and aging mechanism modeling, simulation, and analysis tools, sensor schemes and tools, and non-destructive analysis tools. Continue advanced sensor analysis development efforts to further improve data acquisition and reduce uncertainty in ballistic missile life predictions. Continue to improve the fidelity and precision of non-destructive evaluation tools to increase the capability to determine flaw size, orientation, and location. Continue to support the transition of previous tools, models, data management system to user. Continue long-term validation of tools through long-term aging of sub-scale motors. Continue sub-scale motors dissection to validate the sensor and analytical analysis of each motor. Continue maturation and demonstration of advanced sensor, non-destructive evaluation, modeling and supporting technology development efforts to detect and explain phenomena to further improve data acquisition and reduce uncertainty in ballistic and tactical missile solid rocket motor life predictions.				
FY 2020 Plans: Continue to apply next generation of chemical and aging mechanism modeling, simulation, and analysis tools, sensor schemes and tools, and non-destructive analysis tools. Continue advanced sensor analysis development efforts to further improve data acquisition and reduce uncertainty in ballistic missile life predictions. Continue to improve the fidelity and precision of non-destructive evaluation tools to increase the capability to determine flaw size, orientation, and location. Continue to support the transition of previous tools, models, data management system to user. Continue long-term validation of tools through long-term aging of sub-scale motors. Continue sub-scale motors dissection to validate the sensor and analytical analysis of each motor. Continue maturation and demonstration of advanced sensor, non-destructive evaluation, modeling and supporting technology development efforts to detect and explain phenomena to further improve data acquisition and reduce uncertainty in ballistic and tactical missile solid rocket motor life predictions.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.167 million. Justification for the increase is described in the plans above.				
Accomplishments/Planned Programs Subtotals		20.927	29.220	28.256
		FY 2018	FY 2019	
Congressional Add: Program increase		7.250	0.000	

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 634922 / <i>Space & Missile Rocket Propulsion</i>

	FY 2018	FY 2019
FY 2018 Accomplishments: Conducted Congressionally directed efforts		
FY 2019 Plans: Not Applicable		
Congressional Add: Program increase - chemical apogee engines	0.000	2.500
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts.		
Congressional Add: Program increase - upper stage engine maturation	0.000	8.500
FY 2018 Accomplishments: Not Applicable		
FY 2019 Plans: Conduct Congressionally directed efforts.		
Congressional Adds Subtotals	7.250	11.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

Not Applicable

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>				Project (Number/Name) 635098 / <i>Advanced Aerospace Propulsion</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635098: <i>Advanced Aerospace Propulsion</i>	-	41.256	20.194	18.814	0.000	18.814	20.169	20.889	21.532	22.158	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates, via ground and flight tests, the scramjet propulsion cycle to a technology readiness level appropriate for full integration with other engine cycles (including turbine and rocket-based) to provide the Air Force with transformational military capabilities. The primary focus is on the hydrocarbon-fueled, scramjet engine. Multi-cycle engines will provide the propulsion systems for possible application to support aircraft and weapon platforms operating up to Mach 7. Efforts include: scramjet flow-path optimization to enable operation over the widest possible range of Mach numbers; active combustion control to assure continuous positive thrust (even during mode transition); robust flame-holding to maintain stability through flow distortions; and maximized volume-to-surface area to minimize the thermal load imposed by the high-speed engine. Thermal management plays a vital role in scramjet and combined cycle engines, including considerations for protecting low speed propulsion systems (e.g., turbine engines) during hypersonic flight.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Scramjet Technologies	41.256	20.194	18.814
Description: Develop and demonstrate technologies for a hydrocarbon-fueled scramjet with robust operation up to Mach 7.			
FY 2019 Plans: Initiate scramjet combustor maturation efforts for flight-compliant designs based on results from direct connect testing of medium scale engine components at Aerodynamic and Propulsion Test Unit (APTU). Continue development and demonstration of tactically compliant subsystems, including scramjet engine start system, fuel system, and engine controls. Continue development of scramjet technologies to enhance operability including robust operation during maneuvers. Continue accelerated development and demonstration of tactically-relevant long range high speed strike scramjet engine technologies including ground and flight demonstrations needed for potential follow-on acquisition program.			
FY 2020 Plans: Complete scramjet combustor maturation efforts for flight-compliant designs based on results from direct connect testing of medium scale engine components at APTU. Continue development and demonstration of tactically compliant subsystems, including scramjet engine start system, fuel system, and active engine controls. Continue development of scramjet technologies to enhance operability including robust operation during maneuvers. Continue accelerated development and demonstration of tactically-relevant long range high speed strike scramjet engine technologies including ground and flight demonstrations needed for potential follow-on acquisition program.			
FY 2019 to FY 2020 Increase/Decrease Statement:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 635098 / <i>Advanced Aerospace Propulsion</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 decreased compared to FY 2019 by \$1.380 million. Justification for the decrease is due to higher Air Force Science and Technology priorities.			
Accomplishments/Planned Programs Subtotals	41.256	20.194	18.814

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>				Project (Number/Name) 63681B / <i>Advanced Turbine Engine Gas Generator</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
63681B: <i>Advanced Turbine Engine Gas Generator</i>	-	14.803	28.652	21.831	0.000	21.831	22.183	22.822	23.411	23.979	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates technology to increase turbine engine operational reliability, durability, mission flexibility, and performance while reducing weight, fuel consumption, and cost of ownership. The objective is to provide continuous evolution of technologies into an advanced gas generator in which the performance, cost, durability, repairability, and maintainability can be assessed in a realistic engine environment. The gas generator, or core, is the basic building block of the engine and nominally consists of a compressor, a combustor, a high-pressure turbine, mechanical systems, and core subsystems. Experimental core engine demonstration validates engineering design tools and enhances rapid, low-risk transition of key engine technologies into engineering development, where they can be applied to derivative and/or new systems. These technologies are applicable to a wide range of military and commercial systems including aircraft, missiles, land combat vehicles, ships, and responsive space launch. Component technologies are demonstrated in a core (sub-engine). This project also assesses the impact of low spool components such as; inlet systems, fans, low pressure turbines, exhaust systems, and system level technologies such as; integrated power generators and thermal management systems on core engine performance, and durability in ground demonstrations of engine cores. The core performances of this project are validated on demonstrator engines in the Aircraft Propulsion Subsystem Integration Project of this program. A portion of this project supports the demonstration of adaptive cycle technologies, which develop component technology for an adaptive cycle engine architecture that provides optimized performance, fuel efficiency, and durability for widely varying mission needs.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Core Engine Technologies	6.336	9.268	9.188
Description: Design, fabricate, and demonstrate performance predictions in core engines, using innovative engine cycles and advanced materials for turbofan and for turbojet engines.			
FY 2019 Plans: Continue design of medium-scale efficient core demonstrator. Initiate risk reduction component tests for medium-scale engine advanced fan and core. Initiate build of medium-scale engine. Continue design of large-scale adaptive core concepts. Continue design of bladed disks and bearing systems components for small cruise missile size engine. Continue development of small cruise missile engine demonstrator test plans to improve life prediction capability for bladed disks and bearing systems.			
FY 2020 Plans: Complete detailed design of medium-scale efficient core demonstrator. Continue risk reduction component tests for medium-scale engine advanced fan and core. Continue build of medium-scale engine. Complete conceptual design of large-scale adaptive core concepts. Complete design of bladed disks and bearing systems components for small cruise missile size engine. Complete			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 63681B / <i>Advanced Turbine Engine Gas Generator</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
development of small cruise missile engine demonstrator test plans to improve life prediction capability for bladed disks and bearing systems. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.080 million. Justification for the decrease is described in the plans above.				
Title: High Pressure Ratio Core Engine Technologies Description: Design, fabricate, and demonstrate high overall pressure ratio engine cores to provide increased durability and affordability with lower fuel consumption for turbofan and for turboshaft engines. FY 2019 Plans: Complete risk reduction testing of components for 200lb thrust and 650lb thrust engines. Complete critical design review of 200lb thrust engine. Initiate assembly of advanced concept additive manufacturing heat exchanger for small core engines. Initiate fabrication of recuperator for demonstration of increased core efficiency in small core engines. FY 2020 Plans: Complete several key risk reduction testing of components for small engines (200-800 lbs class). Initiate conceptual and preliminary design of small engine technology: Identify innovative architecture, critical technologies and component designs for efficient, recuperated turbo shaft engines. Continue assembly of advanced concept additive manufacturing heat exchanger for small core engines. Continue fabrication of recuperator for demonstration of increased core efficiency in small core engines. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.094 million. Justification for the increase is described in the plans above.		2.298	3.362	3.456
Title: Adaptive Turbine Engine Core Technologies Description: Design, fabricate, and demonstrate adaptive turbine engine cores to provide increased durability and affordability with lower fuel consumption for turbofan and for turboshaft engines. FY 2019 Plans: Complete Preliminary Design Review and procurement of long lead hardware for advanced air dominance adaptive core demonstrator and risk reduction rigs. Initiate detailed design advanced air dominance adaptive core demonstrator. Initiate component tests of advanced variable turbine and innovative compression rear block designed to accept flow variations caused by variable turbine operation. Complete the evaluation of application of high temperature polymer matrix composite and ceramic matrix composites to reduce system weight and improve cycle efficiency. Complete analyses of adaptive engine technologies operational mission impact. FY 2020 Plans:		6.169	9.022	9.187

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603216F / <i>Aerospace Propulsion and Power Technology</i>	Project (Number/Name) 63681B / <i>Advanced Turbine Engine Gas Generator</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
Complete conceptual design of adaptive engine technology and initiate technology rig tests to decrease risk in core technology testing. Continue component tests of advanced variable turbine and innovative compression rear block designed to accept flow variations caused by variable turbine operation.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.165 million. Justification for the increase is described in the plans above.				
Accomplishments/Planned Programs Subtotals		14.803	21.652	21.831
		FY 2018	FY 2019	
Congressional Add: Program increase - advanced turbine engine gas generator		0.000	7.000	
FY 2018 Accomplishments: Not Applicable				
FY 2019 Plans: Conduct Congressionally directed efforts				
Congressional Adds Subtotals		0.000	7.000	
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				
D. Acquisition Strategy				
N/A				
E. Performance Metrics				
Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.				

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	56.238	55.054	48.408	0.000	48.408	47.116	49.893	50.135	51.229	Continuing	Continuing
633720: <i>EW Quick Reaction Capabilities</i>	-	30.205	30.556	29.454	0.000	29.454	29.313	29.424	29.519	30.217	Continuing	Continuing
63431G: <i>RF Warning & Countermeasures Tech</i>	-	13.645	14.441	11.691	0.000	11.691	10.312	11.448	11.530	11.785	Continuing	Continuing
634335: <i>Cyber Concepts</i>	-	6.095	5.832	2.903	0.000	2.903	3.040	4.434	4.472	4.521	Continuing	Continuing
63691X: <i>EO/IR Warning & Countermeasures Tech</i>	-	6.293	4.225	4.360	0.000	4.360	4.451	4.587	4.614	4.706	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops and demonstrates technologies to support Air Force electronic combat warfighting capabilities. The program focuses on developing components, subsystems, and technologies with potential aerospace combat, special operations, and airlift electronic combat applications. It develops and demonstrates technologies for integrating electronic combat sensors and systems into a fused and seamless whole. It integrates and focuses research efforts in electronic warfare and cyber warfare to rapidly demonstrate a capability for rapid fielding. It develops and demonstrates technologies for navigation and timing in radio frequency (RF) contested and denied environments. It develops and demonstrates advanced technologies for radio frequency electronic combat suites and advanced warning and countermeasure technologies to defeat electro-optical, infrared, and laser threats to aerospace platforms. It also develops and demonstrates technologies that identify and mitigate avionics system cyber vulnerabilities as well as protects avionics and other critical technologies. This program has been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of such program funds would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	60.551	55.319	57.501	0.000	57.501
Current President's Budget	56.238	55.054	48.408	0.000	48.408
Total Adjustments	-4.313	-0.265	-9.093	0.000	-9.093
• Congressional General Reductions	-0.166	-0.265			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.330	0.000			
• Other Adjustments	-2.817	0.000	-9.093	0.000	-9.093

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

Decrease in FY 2020 due to realignment of electronic warfare science and technology funding from PE 0603270F, Electronic Combat Technology, to PE 0602204F, Aerospace Sensors.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>				Project (Number/Name) 633720 / <i>EW Quick Reaction Capabilities</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
633720: <i>EW Quick Reaction Capabilities</i>	-	30.205	30.556	29.454	0.000	29.454	29.313	29.424	29.519	30.217	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project establishes a capability to rapidly assess, develop and demonstrate new electronic warfare concepts, techniques, and capabilities as well as the required position navigation and timing (PNT) technologies and capabilities in the context of systemic electronic warfare (EW) effects (electronic warfare threat interactions) in a congested/contested electromagnetic spectrum, system-of-systems (SoS) environment of the future. It develops disruptive electronic warfare and countermeasures concepts specifically selected for high-impact, game-changing effects; evaluates them in high fidelity virtual and hardware evaluation settings; and demonstrates them in an operationally relevant environment. It establishes and maintains an all-source, physics-based, threat-to-countermeasures electronic warfare systems engineering methodology. It develops a core analytic function, supported by simulation-based wargaming and interactive engineering modeling capabilities to evaluate advanced countermeasures concepts.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Radio Frequency Electronic Warfare	13.594	9.513	10.503
Description: Develop Electronic Warfare focused knowledge databases, engineering models, mission simulations, analysis tools and assessment environments which enable the development of multi-domain electronic warfare technologies. The primary focus is on emulating complex battlespace radio frequency environments, electronic attack effects against emerging, networked weapon systems, and assessing flexible, software-defined electronic warfare systems with non-deterministic performance (for example, utilizing cognitive algorithms).			
FY 2019 Plans: Expand simulations to accommodate advanced electronic warfare systems, and to emulate the radio frequency threats and signal environments for which they're designed. Develop higher fidelity threat system and signal propagation models. Continue developing the tools, methods and demonstrations to assess both the performance of future electronic warfare systems as well as their effectiveness. Continue the development and demonstration efforts to prove the concepts for "full spectrum" countermeasures capabilities. In select situations, develop threat seeker surrogates with which to test emerging electronic warfare technologies. Expand software-in-the-loop and hardware-in-the-loop environments to achieve closed-loop system performance.			
FY 2020 Plans: Continue expansion of simulations to accommodate advanced electronic warfare systems, and to emulate the complex radio frequency threats and signal environments for which they're designed. Continue development of higher fidelity threat system and signal propagation models. Continue developing the tools, methods and demonstrations to assess both the performance of			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>	Project (Number/Name) 633720 / <i>EW Quick Reaction Capabilities</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>future electronic warfare systems as well as their effectiveness including cognitive and autonomous technologies. Continue the development and demonstration efforts to prove the concepts for "full spectrum" countermeasures capabilities. Continue the select development of threat seeker surrogates with which to test emerging electronic warfare technologies. Continue expansion of software-in-the-loop and hardware-in-the-loop environments to achieve closed-loop system performance.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.990 million. Justification for this increase is described in plans above.</p>				
<p>Title: Position, Navigation and Timing for Contested/Denied Environments</p> <p>Description: Develop and transition robust Global Navigation Satellite System capabilities; resilient complementary position, navigation and timing techniques; precise position, navigation and timing technologies for distributed sensing; position, navigation and timing technology to provide position, navigation and timing electronic warfare situational awareness and training; and position, navigation and timing architectures to enable resiliency against the rapidly evolving threat. Efforts will include prototypes and relevant Open Architecture standards where applicable to enable timely technology transition.</p> <p>FY 2019 Plans: Research techniques to securely certify Global Navigation Satellite System software defined radio technology and methods to trust Global Navigation Satellite System. Develop complementary position, navigation and timing techniques which increase the availability of the position, navigation and timing solution as well as increase the precision for radio frequency coherent sensing and electronic warfare. Evolve open architecture standards to allow for integration of Global Navigation Satellite System and complementary position, navigation and timing into future systems. Demonstrate integration of Global Navigation Satellite System position, navigation and timing and datalink-based complementary position, navigation and timing into an resilient embedded Global Positioning System inertial government reference architecture.</p> <p>Previous to FY 2019, some of this work was performed in Radio Frequency Electronic Warfare and Electro-Optical and Infrared (EO/IR) Threat Warning and Countermeasures efforts under Project 633720, EW Quick Reaction Capabilities.</p> <p>FY 2020 Plans: Continue to further research techniques to securely certify Global Navigation Satellite System software defined radio technology and methods to trust Global Navigation Satellite System and integrate into the Navigation Technology Satellite-3 flight experiment. Develop advanced reconfigurable software defined radio navigation receivers to enable spectrum agile systems and integrate into the Navigation Technology Satellite-3 flight experiment. Develop alternative position, navigation and timing techniques which increase the availability of the position, navigation and timing solution as well as increase the precision for radio frequency coherent sensing and electronic warfare. Evolve open architecture standards to allow for integration of Global Navigation Satellite System and alternative position, navigation and timing into future systems. Demonstrate integration of Global Navigation</p>		7.739	16.335	16.336

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>	Project (Number/Name) 633720 / <i>EW Quick Reaction Capabilities</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
Satellite System position, navigation and timing and datalink-based complementary position, navigation and timing into a resilient embedded Global Positioning System inertial (R-EGI) government reference architecture.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.001 million. Justification for this increase is described in plans above.				
Title: Electro-Optical/Infrared Threat Warning and Countermeasures		8.872	4.708	2.615
Description: Develop next generation countermeasure techniques to address the complete range of multispectral (for example, dual band infrared) threats including advanced techniques versus advanced man portable air defense system and air-to-air threats with multimode capabilities. Develop capabilities for situational awareness and countermeasure to integrated air defense systems and associated multispectral threats.				
FY 2019 Plans: Continue test planning and field and flight tests of a proactive infrared countermeasure capability to detect ground based electro-optical/infrared threats. Continue the integration of joint radio frequency and electro-optical/infrared engagement modeling and simulation capabilities to support countering multispectrum (for example, radio frequency and electro-optical/infrared combined) threats. Continue designs and begin field test demonstration of capabilities against multispectral threats. Refine the countermeasure techniques and sources for countermeasures against advanced imaging multispectral sensors to include tower testing against surrogates and representative threats hardware.				
FY 2020 Plans: Continue at range evaluation of next generation high sensitivity focal plane array for proactive detection. Start requirements definition and evaluate acquisition alternatives for a proactive advanced technology demonstration. Start laboratory tests and continue modeling and simulation efforts to support the multispectrum electro-optical/radio frequency countermeasures. Continue advance technique countermeasure at range tests to support requirements definition.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$2.093 million. Funding decreased due to realignment to PE 0602204F, Aerospace Sensors, Project 624920, Electronic Warfare Technology, Electro-Optical/Infrared Threat Warning and Countermeasure Technologies effort.				
Accomplishments/Planned Programs Subtotals		30.205	30.556	29.454
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>	Project (Number/Name) 633720 / <i>EW Quick Reaction Capabilities</i>

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>				Project (Number/Name) 63431G / <i>RF Warning & Countermeasures Tech</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
63431G: <i>RF Warning & Countermeasures Tech</i>	-	13.645	14.441	11.691	0.000	11.691	10.312	11.448	11.530	11.785	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates advanced technologies for radio frequency electronic combat suites, including the required navigation technologies and capabilities, to enhance the survivability of aerospace vehicles and to provide crew situational awareness. The research addresses technologies for missile/threat warning, radio frequency receivers, electronic combat pre-processors, advanced sorting/pre-processing algorithms, and expert software for applications on existing and future electronic combat systems. The research also focuses on the development and demonstration of subsystems and components for generating on-board/off-board radio frequency countermeasure techniques. This includes the development of electronic countermeasures techniques, as well as advanced electronic countermeasures technologies such as antennas, power amplifiers, and preamplifiers.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Electronic Attack	13.645	14.441	11.691
Description: Develop aerospace platform jamming concepts, technologies and techniques to counter advanced radio frequency threats associated with current and future aerospace weapon systems. Provide position, navigation and system resilience via open architecture solutions.			
FY 2019 Plans: Continue research into radio frequency receiver technologies that will better detect threats, measure more radio frequency features with greater accuracy, identify or classify signals more reliably, track and predict signals, and use reasoning algorithms to reduce ambiguities and errors, and deduce greater knowledge from the radio frequency spectrum. Continue development of countermeasures toward explicit, underserved threat weapon systems, with an emphasis on chamber and field testing for validation. Continue research and development of novel multi-domain electronic attack methods and tactics to include distributed operations. Initiate the study, research and/or development of merged autonomy and electronic warfare technologies. Continue expansion of modeling, simulation and laboratory assessment environments commensurate with technologies being researched, developed and tested.			
FY 2020 Plans: Continue research into radio frequency receiver technologies that will better detect threats, measure more radio frequency features with greater accuracy, identify or classify signals more reliably, track and predict signals, and use reasoning algorithms to reduce ambiguities and errors, and deduce greater knowledge from the radio frequency spectrum. Continue development of countermeasures toward explicit, underserved threat weapon systems, with an emphasis on chamber and field testing for validation. Continue research and development of novel multi-domain electronic attack methods and tactics to include			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>	Project (Number/Name) 63431G / <i>RF Warning & Countermeasures Tech</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
distributed operations. Continue expansion of modeling, simulation and laboratory assessment environments commensurate with technologies being researched, developed and tested including cognitive and autonomous electronic warfare technologies. Continue the study, research and/or development of merged autonomy and electronic warfare technologies.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$2.750 million. Funding decreased due to realignment to PE 0602204F, Aerospace Sensors, Project 624920, Electronic Warfare Technology, Radio Frequency Countermeasures Technologies effort.			
Accomplishments/Planned Programs Subtotals	13.645	14.441	11.691

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>				Project (Number/Name) 634335 / <i>Cyber Concepts</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
634335: <i>Cyber Concepts</i>	-	6.095	5.832	2.903	0.000	2.903	3.040	4.434	4.472	4.521	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates methods to discover cyber susceptibilities, assess avionics systems, formulate mitigation strategies, and investigate use of tools and technologies to automate this process. It is designed to apply developed vulnerability discovery, vulnerability mitigation, and cyber protection technology to avionics systems and components and embedded systems. This involves technologies for trusted sensors and trusted systems that deter exploitation of our critical hardware and software. This project aims to develop cyber resilience and protect systems through adaptation of the system to the threat. It demonstrates these technologies in open and adaptable architectures for system integration in field demonstrations and proves out the technologies through rapid integration of sensors and architectures for technology transition. It integrates research efforts in electronic and cyber warfare to rapidly demonstrate a capability for rapid fielding.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Avionics Cyber Vulnerabilities	3.386	3.241	1.613
Description: Develop and demonstrate methods, techniques, and technical tools to enable, assist, and improve the vulnerability discovery processes. Use developed tools and techniques to assess avionics boxes, systems, busses, and components. Investigate techniques to mitigate discovered vulnerabilities. Develop and demonstrate mitigation and protection technologies on future concept platforms for adaptability and resilience.			
FY 2019 Plans: Complete transition of assessment tools and continue to develop and transition mitigation technologies. Investigate and advance architectural concepts that enable cost-effective and rapid integration of revolutionary sensor capabilities. This allows system flexibility required for future operations. Architecture includes features to make it cyber secure.			
FY 2020 Plans: Continue to transition vulnerability mitigation technologies to address enduring issues with legacy weapon systems. Increase efforts to demonstrate next-generation architecture capabilities, providing integration support for emerging technologies such as autonomy, alternative-navigation technologies, open system architecture standards and approaches, and multispectral and distributed intelligence surveillance and reconnaissance and electronic warfare. Transition next-generation architectures to adopting programs/platforms, and open architecture approaches to rapidly integrate advanced mission system capability for next-generation architectures.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$1.628 million. Funding decreased due to realignment to PE 0602204F, Aerospace Sensors, Project 622005, Cyber Technology, Vulnerability Mitigation effort.			
Title: Avionics Cyber Protections	2.709	2.591	1.290

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>	Project (Number/Name) 634335 / <i>Cyber Concepts</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Description: Develop and demonstrate advanced automated analysis tools and protection techniques to prevent exploitation of cyber susceptibilities in avionics systems. This strategy would include discovery and mitigation of likely attack vectors, remediation of susceptibilities, and safeguards to assure the integrity of embedded software.</p> <p>FY 2019 Plans: Continue to extend research on a suite of protection tools with focus on their application to unmanned aircraft system platforms. Continue to investigate automation and optimization of malware detection and classification work using machine learning techniques. Develop a patterns database that detects and classifies benign and malicious behaviors, and validate proof-of-concept for x86 computer architectures. Investigate and create architecture specific translators to provide input to behaviors database to further validate the concept.</p> <p>FY 2020 Plans: Enhance and extend cyber protection tools, techniques and test beds for manned and unmanned air vehicles, mission and support equipment. Demonstrate a cyber defense-in-depth by integrating software, firmware and hardware-assisted protection technologies. Develop system integration laboratory capabilities to develop, integrate, and test real-time cyber protections for avionics; intelligence, surveillance, and reconnaissance; positioning, navigation, and timing; and other systems. Develop test samples to demonstrate the effectiveness of cyber protections. Flight test and demonstrate advanced cyber protection capabilities to reduce the risk to programs of record. Collaborate with program offices and end-users to transition cyber protection technologies. Leverage open system architecture standards and approaches to demonstrate cyber protections for current and next-generation architectures.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$1.301 million. Funding decreased due to realignment to PE 0602204F, Aerospace Sensors, Project 622005, Cyber Technology, Adaptive Cyber Protections effort.</p>			
Accomplishments/Planned Programs Subtotals	6.095	5.832	2.903

C. Other Program Funding Summary (\$ in Millions) N/A
Remarks
D. Acquisition Strategy N/A

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>	Project (Number/Name) 634335 / <i>Cyber Concepts</i>

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>				Project (Number/Name) 63691X / <i>EO/IR Warning & Countermeasures Tech</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
63691X: <i>EO/IR Warning & Countermeasures Tech</i>	-	6.293	4.225	4.360	0.000	4.360	4.451	4.587	4.614	4.706	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates the advanced warning and countermeasure technologies required to negate electro-optical/infrared and laser threats to aerospace platforms. Develops off-board (decoys and expendables) and on-board countermeasure technologies for aircraft self-protection to provide robust, affordable solutions for protection against infrared missiles with autonomous seekers, multi-spectral threats, laser-guided weapons, and electro-optical/infrared tracking systems used to direct electro-optical/infrared and radar-guided missiles.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Advanced Electro-Optical/Infrared Warning and Countermeasure Technologies	6.293	4.225	4.360
Description: Analyze the vulnerabilities of current infrared missile systems and future imaging infrared sensors. Develop advanced countermeasure system techniques to exploit vulnerabilities for use against infrared and electro-optical guided missile threats. Develop advanced optical and infrared sensor systems for airborne and space situational awareness and threat warning.			
FY 2019 Plans: Continue countermeasure development and field testing of new threats to include new jam codes and countermeasure techniques. Continue to incorporate proactive infrared countermeasures capabilities into Modeling System for Advanced Investigation of Countermeasures (MOSAIC). Laboratory testing of the low cost missile warning capabilities as designed and built into current missile warning system form factor. Flight test the low cost missile warning capabilities and refine design alternative and conduct critical experiments for long range missile warning. Stand up the High altitude threat warning capabilities and begin characterization testing for advanced laser warning options. Start design and tradeoff phase for the proactive critical experiment.			
FY 2020 Plans: Continue threat characterization and countermeasures development and field testing of new threats to include new jam codes and countermeasure techniques. Continue to work with customers to determine impacts on current systems. Continue flight test of the low cost missile warning capabilities. Conduct critical experiments of long range missile warning technologies. Start incorporation of Modeling System for Advanced Investigation of Countermeasures and Radio Frequency engagement model development to meet the multispectral and multispectrum threats.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.135 million. Justification for this increase is described in plans above.			
Accomplishments/Planned Programs Subtotals	6.293	4.225	4.360

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603270F / <i>Electronic Combat Technology</i>	Project (Number/Name) 63691X / <i>EO/IR Warning & Countermeasures Tech</i>
C. Other Program Funding Summary (\$ in Millions) N/A		
Remarks		
D. Acquisition Strategy N/A		
E. Performance Metrics Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.		

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force / BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	94.946	70.734	70.525	0.000	70.525	80.358	75.234	72.413	69.600	Continuing	Continuing
632181: <i>Spacecraft Payloads</i>	-	17.198	21.093	13.176	0.000	13.176	13.356	16.823	17.159	17.490	Continuing	Continuing
633834: <i>Integrated Space Technology Demonstrations</i>	-	27.896	16.362	18.856	0.000	18.856	22.486	13.981	17.538	22.870	Continuing	Continuing
634400: <i>Space Systems Protection</i>	-	35.688	8.419	7.708	0.000	7.708	7.471	7.885	8.042	8.204	Continuing	Continuing
635021: <i>Space Systems Survivability</i>	-	2.748	1.571	1.581	0.000	1.581	1.611	1.643	1.675	1.709	Continuing	Continuing
63682J: <i>Spacecraft Vehicles</i>	-	11.416	23.289	29.204	0.000	29.204	35.434	34.902	27.999	19.327	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops, integrates, and demonstrates space technologies in the areas of spacecraft payloads, spacecraft protection, spacecraft vehicles, and space systems survivability. The integrated space technologies are demonstrated by component or system level tests on the ground or in flight. Efforts in this program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	58.910	54.895	53.979	0.000	53.979
Current President's Budget	94.946	70.734	70.525	0.000	70.525
Total Adjustments	36.036	15.839	16.546	0.000	16.546
• Congressional General Reductions	-0.101	-0.161			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	31.000	16.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	8.000	0.000			
• SBIR/STTR Transfer	-2.863	0.000			
• Other Adjustments	0.000	0.000	16.546	0.000	16.546

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 632181: *Spacecraft Payloads*

Congressional Add: *Program Increase - radiation hardened microelectronics*

Congressional Add: *Program increase - radiation hardened microelectronic processors*

Congressional Add Subtotals for Project: 632181

Project: 634400: *Space Systems Protection*

Congressional Add: *Program increase*

Congressional Add: *Program increase - commercial SSA consortia/testbed*

Congressional Add Subtotals for Project: 634400

Project: 63682J: *Spacecraft Vehicles*

Congressional Add: *Program increase - space laser communications systems*

Congressional Add Subtotals for Project: 63682J

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	5.809	0.000
	0.000	6.000
	5.809	6.000
	9.682	0.000
	14.522	0.000
	24.204	0.000
	0.000	10.000
	0.000	10.000
	30.013	16.000

Change Summary Explanation

Increase in FY 2018 due to \$8.000 million reprogramming for Battle Management Command and Control Joint Emergent Operational Need.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity	R-1 Program Element (Number/Name)
3600: <i>Research, Development, Test & Evaluation, Air Force / BA 3: Advanced Technology Development (ATD)</i>	PE 0603401F / <i>Advanced Spacecraft Technology</i>

Increase in FY 2020 due to greater emphasis on enhancing research and development in small satellite technologies.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>				Project (Number/Name) 632181 / <i>Spacecraft Payloads</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
632181: <i>Spacecraft Payloads</i>	-	17.198	21.093	13.176	0.000	13.176	13.356	16.823	17.159	17.490	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project funds the development, demonstration, and evaluation of radiation-hardened space electronic hardware, satellite control hardware, and software for advanced satellite surveillance operations. Future improved space-qualifiable electronics and software for data and signal processing will be more interchangeable, interoperable, and standardized. In the near-term, this project's work concentrates on converting (for example, radiation-hardening) commercial data and signal processor technologies for use in Air Force space systems. For mid-term applications, this project merges advanced, radiation-hardened space processor, memory, and interconnect technologies with commercially-derived, open system architectures to develop and demonstrate robust, on-board processing capabilities for 21st century Department of Defense satellites. In the long-term, this project area focuses on developing low-cost, easily modifiable software and hardware architectures for fully autonomous constellations of intelligent satellites capable of performing all mission related functions without operator intervention.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Advanced Space Electronics	2.946	3.669	3.197
Description: Develop microelectronic devices, including radiation-hardened data processors and high-density hardened memories, advanced packaging technologies, and micro-electro-mechanical system components and applications.			
FY 2019 Plans: Complete verification of split-fabrication as trusted method. Continue the productization stage of electron-beam manufacturing capability. Continue to lead trusted Field-Programmable Gate Array development. Continue development of next generation memory technologies for space. Oversee qualification of processing and memory technology developments. Continue assessments of tolerance of advanced electronic circuit components to space radiation environmental conditions. Continue development of novel payload processor technologies and necessary memory to support it.			
FY 2020 Plans: Complete the productization stage of electron-beam lithography manufacturing capability. Continue leading trusted Field-Programmable Gate Array development and begin space qualification planning. Continue development of next generation memory technologies for space. Oversee qualification of next generation space processor development and planning memory technology development qualification planning. Continue assessments of tolerance of advanced electronic circuit components to space radiation environmental conditions. Continue development of novel payload processor technologies and architectures, and the electronic memory necessary to support them. Begin development of heterogeneous processing payload architecture for future on-orbit experiment.			
FY 2019 to FY 2020 Increase/Decrease Statement:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 632181 / <i>Spacecraft Payloads</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
FY 2020 decreased compared to FY 2019 by \$0.472 million. Justification for the decrease is described in the plans above.				
<p>Title: Advanced Space Modeling and Simulation Tools</p> <p>Description: Develop modeling, simulation, and analysis tools for space-based surveillance systems, space capability protection technologies, access/mobility technologies, and flight experiments.</p> <p>FY 2019 Plans: Apply and analyze models for cross-platform modeling, simulation, and analysis support of multi-mission geosynchronous space flight demonstration. Continue trade studies and utility analysis for concept development of emerging space technologies, future space flight experiments (with associated software algorithms), and commercial space applications.</p> <p>FY 2020 Plans: Begin leveraging multiple domain analyses across space and terrestrial missions with model-test-model in support of multi-mission geosynchronous space flight demonstrations. Initiate simultaneous trade studies using utility analyses for concept maturation of emergent space technologies for space flight experiments and applications in commercial space.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.102 million. Justification for the increase is described in the plans above.</p>		0.864	0.851	0.749
<p>Title: Advanced Space Sensors</p> <p>Description: Develop space infrared technology and hardened focal plane detector arrays to enable acquisition, tracking, and discrimination of hot targets, as well as "cold body" objects.</p> <p>FY 2019 Plans: Continue to develop III-V alternative infrared detector materials for space environments. Deliver a scanning Focal Plane Array for missile warning capability demonstration during laser impingement. Characterize performance of scanning Focal Plane Array in representative space environment to include natural and man-made radiation including focused photons will take place to identify any shortfalls that may be present and resolve if necessary.</p> <p>FY 2020 Plans: Continue to develop III-V alternative infrared detector materials for space environments. Continue development of scanning and staring focal plane arrays for missile warning capability demonstrations during laser impingement. Continue performance characterization of visible through infrared focal plane arrays in representative space environments, including natural and man-made radiation, i.e. focused photons, to identify and resolve any shortfalls impeding the technology transition.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>		1.686	2.522	2.070

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 632181 / <i>Spacecraft Payloads</i>
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B. Accomplishments/Planned Programs (\$ in Millions)

FY 2020 decreased compared to FY 2019 by \$0.452 million. Justification for the increase is described in the plans above.

	FY 2018	FY 2019	FY 2020
Title: Positioning, Navigation, and Timing Space Payload Technologies	5.893	8.051	7.160
Description: Develop, validate, and transition technologies that: enable new, or enhance existing, United States positioning, navigation, and timing satellite capabilities by increasing resiliency and availability of accuracy; and/or increase the affordability of providing current capabilities. Develop, validate, and transition technologies to meet identified Air Force Space Command/Space and Missile Systems Center positioning, navigation, and timing space payload technology needs.			
FY 2019 Plans: Conduct preliminary and critical design activities for multiple modular/hostable positioning, navigation, and timing payloads/payload technologies for future Global Positioning System and Global Positioning System augmentation satellites.			
FY 2020 Plans: Mature developing advanced positioning, navigation, and timing signals for experimentation on the Navigation Technology Satellite - 3 flight experiment. Conduct preliminary assessments of broadband components for use in satellite payloads for Precision Navigation and Timing. Test reprogrammability aspects of on-orbit reprogrammable digital waveform generator and explore use cases for enterprise reprogrammability.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.891 million. Justification for the increase is described in the plans above			
Accomplishments/Planned Programs Subtotals	11.389	15.093	13.176

	FY 2018	FY 2019
Congressional Add: Program Increase - radiation hardened microelectronics	5.809	0.000
FY 2018 Accomplishments: Conducted Congressionally directed effort		
FY 2019 Plans: Not applicable		
Congressional Add: Program increase - radiation hardened microelectronic processors	0.000	6.000
FY 2018 Accomplishments: Not applicable		
FY 2019 Plans: Conducted Congressionally directed effort		
Congressional Adds Subtotals	5.809	6.000

C. Other Program Funding Summary (\$ in Millions)

N/A

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 632181 / <i>Spacecraft Payloads</i>

C. Other Program Funding Summary (\$ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>				Project (Number/Name) 633834 / <i>Integrated Space Technology Demonstrations</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
633834: <i>Integrated Space Technology Demonstrations</i>	-	27.896	16.362	18.856	0.000	18.856	22.486	13.981	17.538	22.870	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project is a series of advanced technology demonstrations designed to address mission needs by applying emerging technologies from the Air Force Research Laboratory, other United States government laboratories, and industry. These technologies are integrated into system-level demonstrations that are used to test, evaluate, and validate the technologies in a relevant environment.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Integrated Satellite Demonstrations	27.896	16.362	18.856
Description: Develop satellite technologies for integrated, robust, and flexible satellite demonstrations building on previous work and leveraging investments by other organizations.			
FY 2019 Plans: Conclude on-orbit operations; complete experimental flight operations of hypertemporal imaging sensor, integrated on-board sensing, threat assessment and autonomy payload, and increase autonomy and safety of advanced proximity operations. Begin transition of spacecraft operations to Air Force Space Command. Continue refining space and ground segments architecture and initial prototype hardware/software for an advanced Global Positioning System space-based integrated demonstration for contested environments with a projected launch in FY 2023.			
FY 2020 Plans: Conclude on-orbit operations; complete and close-out experimental flight operations of spacecraft, hypertemporal imaging sensor, integrated on-board sensing, threat assessment and autonomy payload, and advanced proximity operations. Complete final reports for spacecraft, payloads and experiments. Complete transition of spacecraft operations to Air Force Space Command. Continue space segment components and sub-systems development with a focus on breadboard test and verification results for next generation navigation test satellites. Continue payload and user equipment development and complete user equipment and system software compatibility review to support a projected FY 2023 launch. Conduct on-orbit demonstration of a Geosynchronous orbit small satellite extending the maturity of multiple communication technologies and operational concepts for future small satellites. Continue on-orbit demonstrations of multiple formation flying satellites for near autonomous formation control. Leverage opportunities to fly demonstrations and prototypes, where successes can identify quick transition to next generation technology needs. Coordinate a manifest timeline for critical space projects prioritizing Air Force Space Command technical, security, and operational development requirements. Utilize the Long Duration Propulsive Evolved Expendable Launch Vehicle Secondary Payload Adaptor launch schedule and other prospects to quickly fly demonstrations and prototypes. Mature			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 633834 / <i>Integrated Space Technology Demonstrations</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>payloads from concept proposal to leverage commercial Low Earth orbit constellations. Milestones for these efforts are a Systems Requirements Review and a Preliminary Design Review. Deliverables will be a preliminary system design package and a system interface document.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$2.494 million. Funding increased due to additional small satellite technology demonstration activities.</p>			
Accomplishments/Planned Programs Subtotals	27.896	16.362	18.856

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>				Project (Number/Name) 634400 / <i>Space Systems Protection</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
634400: <i>Space Systems Protection</i>	-	35.688	8.419	7.708	0.000	7.708	7.471	7.885	8.042	8.204	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates tools, instruments, and mitigation techniques required to assure operation of United States space assets in hostile warfighting environments. The project performs assessments of critical components and subsystems, and evaluates susceptibility and vulnerability to radio frequency and laser threats. This project also develops technologies that mitigate identified vulnerabilities. Technologies are developed and demonstrated to support balanced satellite protection strategies for detecting and avoiding threats and operating in a hostile space environment.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Space Situational Awareness Capability Development	3.619	2.194	1.409
Description: Develop tools and technologies that advance space-based proximity awareness capabilities and enable protection and countermeasure courses of action. Efforts will assess a variety of phenomenologies and concepts in response to multiple threat classes and scenarios.			
FY 2019 Plans: Develop and integrate processing techniques into evolved operations centers to autonomously detect, track, identify and characterize satellites to meet timelines needed for implementation of courses of actions mitigating potential gaps for evolving threats. Initiate development of prototypes utilizing multi-phenomenology based on the observables indicating a potential threat. Begin conducting an integrated ground and space experiment for space situational awareness with available sensors.			
FY 2020 Plans: Continue to develop and integrate processing techniques into evolved operations centers to autonomously detect, track, identify and characterize satellites to meet timelines needed for implementation of courses of actions mitigating potential gaps for evolving threats. Continue to further develop prototypes utilizing multi-phenomenology based on the observables indicating a potential threat to mitigate knowledge gaps. Continue to conduct an integrated ground and space experiment for space situational awareness with available sensors.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.785 million. Justification for the decrease is described in the plans above.			
Title: Space Indicators and Warning Research	4.152	2.651	2.182
Description: Develop passive satellite countermeasures and mitigation techniques for current and future threats to satellites.			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 634400 / <i>Space Systems Protection</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p><i>FY 2019 Plans:</i> Conduct RED-vs-BLUE space cyber indications and warning experimentation utilizing the on-orbit research satellite. Evaluate the efficacy of multi-spectrum indications and warning technology within the space resiliency testbed.</p> <p><i>FY 2020 Plans:</i> Conduct RED-vs-BLUE space-cyber experiment campaign with 50th Space Wing and other government agency partners, utilizing an on-orbit space platform. Evaluate technology solutions, and develop concepts of operation and tactics, techniques, and procedures for satellite operations in a cyber-contested space environment. Utilize space resiliency testbed to integrate and assess technology solutions for a projected FY 2021 on-orbit experiment campaign.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$0.469 million. Justification for the decrease is described in the plans above.</p>			
<p><i>Title:</i> Spacecraft Threat Detection</p> <p><i>Description:</i> Develop active satellite local space awareness technologies and exploitation tools for satellite systems.</p> <p><i>FY 2019 Plans:</i> Complete advanced technology in on-board threat detection and course-of-action generation and response using live satellite data. Continue advanced technology development for enterprise-level situation monitoring and demonstrate concepts of space battle management command and control through experimentation with ground stations and flight experiments. Initiate advanced autonomy demonstrations to prove advanced concepts in multidomain real-time command and control. Expand our threat warning and response portfolio, including further maturation of both on board and off board threat sensor suites and supporting computing / comm systems. Demonstrate and experiment with prototype threat warning and response systems within the space resiliency lab. Integrate response options into the Air Force Research Laboratory's space resiliency lab in order to conduct end-to-end multi-spectral threat and response scenarios.</p> <p><i>FY 2020 Plans:</i> Continue to develop advanced software related technology for on-board threat detection and course-of-action generation and response using live satellite data. Continue advanced technology development for enterprise-level situation monitoring and demonstrate concepts of space battle management command and control through experimentation with ground stations and flight experiments. Perform ground based demonstration of multi-domain command and control using space based assets. Initiate advanced autonomy demonstrations to prove advanced concepts in multi-domain real-time command and control. Plan for flight demonstration of satellite autonomy technologies with an emphasis on on-board planning systems. Demonstrate and experiment with prototype threat warning and response systems within an integrated multi-domain testbed.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i></p>	3.713	3.574	4.117

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 634400 / <i>Space Systems Protection</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$0.543 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	11.484	8.419	7.708

	FY 2018	FY 2019
Congressional Add: Program increase	9.682	0.000
FY 2018 Accomplishments: Conducted Congressionally directed effort		
FY 2019 Plans: Not applicable		
Congressional Add: Program increase - commercial SSA consortia/testbed	14.522	0.000
FY 2018 Accomplishments: Conducted Congressionally directed effort		
FY 2019 Plans: Not applicable		
Congressional Adds Subtotals	24.204	0.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 635021 / <i>Space Systems Survivability</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635021: <i>Space Systems Survivability</i>	-	2.748	1.571	1.581	0.000	1.581	1.611	1.643	1.675	1.709	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates technologies to improve space system survivability and reliability of current and future Department of Defense space systems that must continue operation despite natural space hazards. It develops and demonstrates cost-effective solutions to mitigate hazardous space environmental interactions including electrical charge buildup and electronics failures due to both single radiation events and long-term radiation doses.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Spacecraft Survivability/Reliability	2.748	1.571	1.581
Description: Develop technologies to provide improved space radiation and ionospheric hazard specification and forecasting.			
FY 2019 Plans: Continue exploitation of data from on-orbit radiation remediation mission for inclusion in standard radiation belt model for satellite design. Transition updated radiation model to industry with modular architecture, additional data sources, and improved usability. Select concept to proceed to detailed design phase for next-generation highly-miniaturized energetic particle sensor for use in contested space. Begin anomaly attribution tool spiral two demonstration and transition to operational use with common ground system. Continue investigation and improvement of the forecasting of solar radio events that impact Air Force operational systems.			
FY 2020 Plans: Continue updating standard radiation belt model for satellite design and complete transition. Mature next-generation highly-miniaturized energetic charged particle sensor for use in contested space. Continue spiral two demonstration of anomaly attribution tool and incorporate next-generation models for enhanced exploitation of sensor data. Initiate development and demonstration of tools to specify impacts of the ionosphere and near-earth space environment dynamics on Department of Defense systems to support strategic, operational, and tactical users.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.010 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	2.748	1.571	1.581

C. Other Program Funding Summary (\$ in Millions)

N/A

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 635021 / <i>Space Systems Survivability</i>

C. Other Program Funding Summary (\$ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>				Project (Number/Name) 63682J / <i>Spacecraft Vehicles</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
63682J: <i>Spacecraft Vehicles</i>	-	11.416	23.289	29.204	0.000	29.204	35.434	34.902	27.999	19.327	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates compact, low-cost, spacecraft power generation, storage, distribution, and thermal management technologies, including cryogenic cooling technologies. This project also develops composites for spacecraft structures and technologies for spacecraft control and mechanisms.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Title: Space Power Technologies</p> <p>Description: Develop power generation space technologies such as multi-junction solar cells, thin-film solar cells, lightweight solar cell arrays, and radiation resistant solar cell modules.</p> <p>FY 2019 Plans: Continue development of mitigation approaches for thermal excursion in resilient arrays. Continue on-orbit flight experiment development for resilient array technologies.</p> <p>FY 2020 Plans: Continue on-orbit flight experiment development for advanced solar cells, solar arrays, and batteries. Target integration with small, experimental satellites to leverage system-level developments. Further development of on-orbit directed energy sensing approaches.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.002 million. Justification for the increase is described in the plans above.</p>	1.062	1.063	1.065
<p>Title: Spacecraft Structures Technologies</p> <p>Description: Develop, integrate, and demonstrate composite spacecraft structures and thermal technologies for deployable structures, antennas, electronics cooling, and structural sensing.</p> <p>FY 2019 Plans: Complete ground experimentation to test affordable deployable antennas for denied area communication and high-gain, anti-jam Global Positioning System applications. Continue integrated experiment concepts testing structures and thermal technologies for high energy density, full spectrum radio frequency reconfigurability, adaptability, and protection. Initiate integrated ground experiment or flight experiment for extremely thin, multi-mission, radio frequency antennas for ensured capability in highly contested environments.</p> <p>FY 2020 Plans:</p>	1.061	1.061	1.415

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 63682J / <i>Spacecraft Vehicles</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Complete integrated experiments testing structures and thermal technologies for high energy density, full spectrum radio frequency reconfigurability, adaptability, and protection. Complete integrated ground experiment or flight experiment for extremely thin, multi-mission, radio frequency antennas for ensured capability in highly contested environments. Initiate integrated ground experiment or flight experiment for high-power small satellites technologies.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.354 million. Justification for the increase is described in the plans above.</p>				
<p>Title: On-Orbit Satellite Controls</p> <p>Description: Develop technologies for spacecraft controls and mechanisms for on-orbit applications.</p> <p>FY 2019 Plans: Continue testing of advanced computer-vision based navigation algorithms and software for precision spacecraft relative motion control missions.</p> <p>FY 2020 Plans: Complete testing of advanced computer-vision based navigation algorithms and software for precision spacecraft relative motion control missions. Initiate experiments with algorithms using on-orbit data collected from past missions.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.001 million. Justification for the increase is described in the plans above.</p>		0.414	0.415	0.416
<p>Title: Space Communication and Control Technologies</p> <p>Description: Develop technologies for next-generation space communications terminals and equipment, along with methods/ techniques to enable future space system operational command and control concepts.</p> <p>FY 2019 Plans: Support launch of W and V frequency band flight instrument. Support execution of a W and V band propagation experiment. Conduct development and technology demonstrations to address future military satellite communications capability and technology needs, for example, high-gain antenna, high-power amplifiers, low-noise amplifiers, cognitive / resilient networks, reconfigurable satellite radios / transponders, and anti-jam signal processing technologies. Support development and demonstration of novel laser communications technology.</p> <p>FY 2020 Plans: Continue support of planned five-year W/V-band propagation experiment. Support ground terminal operations, maintenance, and re-deployments. Collect and analyze data to statistically characterize atmospheric propagation effects and correlate to meteorological parameters. Conduct research and development to address future military satellite communications</p>		1.822	3.629	12.001

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 63682J / <i>Spacecraft Vehicles</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>capability and technology needs, for example, high-gain antenna, cognitive/resilient/ambient networks, reconfigurable satellite radios / transponders, and anti-jam signal processing technologies. Support development and demonstration of novel laser communications technologies such as low size, weight, power and cooling free space optical communication terminals. Continue development of space-qualified V-band high power amplifier technology. Initiate development of W/V-band satellite transponder for on-orbit experiment and demonstration. Initiate systems engineering and technology risk-reduction for W/V-band ground terminals.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$8.372 million. Funding increased due to additional development of on-orbit experimental W/V-band satellite communications system.</p>				
<p>Title: Advanced Alternative Navigation Technologies</p> <p>Description: Develop new atomic clock technologies and transition these technologies to industry for potential application to future positioning, navigation, and timing space considerations.</p> <p>FY 2019 Plans: Test industry-transitioned clock technology being built into flight experiment payload units for flight testing. Finalize integration and testing of clock engineering models. Start packaging of radiation-hardened, ultra-stable laser needed for cold-atom atomic clocks, accelerometers and gyroscopes operating in space or nuclear environments. Start testing of technology that leverages communications links to provide positioning and time knowledge, and continue second spiral demonstration of performance on hand held military radios to inform technology development activity.</p> <p>FY 2020 Plans: Finish packaging of radiation-hardened, ultra-stable laser. Complete integration of advanced clock technology onto flight experiment payload for space demo. Begin preliminary designs of gravity gradiometer test bed with cold atom system. Initiate development and design of novel inertial sensor technologies. Conduct trade studies. Begin design and validation of radiation-hardened electronics for inertial sensors in strategic environments. Establish modelling and simulation capability for design validation</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$7.186 million. Funding increase due to renewed emphasis on advanced clock technology development.</p>		7.057	7.121	14.307
Accomplishments/Planned Programs Subtotals		11.416	13.289	29.204

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603401F / <i>Advanced Spacecraft Technology</i>	Project (Number/Name) 63682J / <i>Spacecraft Vehicles</i>
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	FY 2018	FY 2019
Congressional Add: Program increase - space laser communications systems	0.000	10.000
FY 2018 Accomplishments: Not applicable		
FY 2019 Plans: Conducted Congressionally directed effort		
Congressional Adds Subtotals	0.000	10.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity					R-1 Program Element (Number/Name)							
3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>					PE 0603444F / <i>Maui Space Surveillance System (MSSS)</i>							
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	9.755	10.674	11.878	0.000	11.878	12.094	12.319	11.728	11.968	Continuing	Continuing
634868: <i>Maui Space Surveillance System</i>	-	9.755	10.674	11.878	0.000	11.878	12.094	12.319	11.728	11.968	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program funds ground-based optical space situational awareness (SSA) technology development and demonstration at the Maui Space Surveillance System (MSSS) in Hawaii, as well as the operation and upgrade of the facility. Efforts in this program have been coordinated through the Department of Defense (DOD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	10.433	10.674	11.878	0.000	11.878
Current President's Budget	9.755	10.674	11.878	0.000	11.878
Total Adjustments	-0.678	0.000	0.000	0.000	0.000
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-0.115	0.000			
• Other Adjustments	-0.563	0.000	0.000	0.000	0.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)	R-1 Program Element (Number/Name) PE 0603444F I Maui Space Surveillance System (MSSS)
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C. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
<p>Title: Operate and Upgrade Maui Space Surveillance System</p> <p>Description: Operate and upgrade the Maui Space Surveillance System (MSSS) to support development, demonstration, and integration of ground-based optical space situational awareness (SSA) technologies.</p> <p>FY 2019 Plans: Continue to maintain Maui Space Surveillance System facility and experimental equipment in a mission-ready state. Perform needed upgrades and modernization to keep facilities and equipment in good working order and allow Maui Space Surveillance System to perform efficiently and reliably. Operate Maui Space Surveillance System facility for development and demonstration of ground based optical space situational awareness capabilities in conjunction with customer programs and an operational space situational awareness mission. Accept control of dynamic telescope system operations into Maui Space Surveillance System capability baseline as components are generated.</p> <p>FY 2020 Base Plans: Continue to maintain Maui Space Surveillance System (MSSS) facility and experimental equipment in a mission-ready state. Perform needed upgrades and modernization to keep facilities and equipment in good working order and allow Maui Space Surveillance System to perform efficiently and reliably. Continue to operate Maui Space Surveillance System facility for development and demonstration of ground based optical space situational awareness (SSA) capabilities in conjunction with customer programs and an operational Space Situational Awareness mission. Continue to accept control of geosynchronous satellite imaging capability, collecting images as requested by mission partners. Begin transition of dynamic telescope system operations into Maui Space Surveillance System capability baseline.</p> <p>FY 2020 OCO Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$1.204 million. Funding increased due to additional support for facility security.</p>	8.840	10.674	11.878	0.000	11.878
<p>Title: Geosynchronous Object Sensor</p> <p>Description: Develop and demonstrate dual-use integrated sensor technology for imaging of geosynchronous objects as well as other long-range applications.</p>	0.915	0.000	0.000	0.000	0.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)	R-1 Program Element (Number/Name) PE 0603444F I Maui Space Surveillance System (MSSS)
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C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
FY 2019 Plans: This work was completed in FY 2018.					
FY 2020 Base Plans: Not applicable					
FY 2020 OCO Plans: Not Applicable					
FY 2019 to FY 2020 Increase/Decrease Statement: Not Applicable					
Accomplishments/Planned Programs Subtotals	9.755	10.674	11.878	0.000	11.878

D. Other Program Funding Summary (\$ in Millions)
 N/A

Remarks

E. Acquisition Strategy
 N/A

F. Performance Metrics
 Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)	R-1 Program Element (Number/Name) PE 0603456F I Human Effectiveness Advanced Technology Development
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	30.153	36.420	37.542	0.000	37.542	36.237	37.069	37.818	38.574	Continuing	Continuing
635323: Directed Energy Bioeffects Parameters	-	4.566	5.251	5.154	0.000	5.154	5.280	6.602	6.736	6.871	Continuing	Continuing
635324: Human Dynamics and Terrain Demonstration	-	5.122	5.408	5.886	0.000	5.886	6.001	7.446	7.597	7.749	Continuing	Continuing
635325: Mission Effective Performance	-	5.984	6.795	6.930	0.000	6.930	7.069	7.213	7.358	7.505	Continuing	Continuing
635327: Warfighter Interfaces	-	14.481	18.966	19.572	0.000	19.572	17.887	15.808	16.127	16.449	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops and demonstrates technologies to enhance Airman performance and effectiveness in the aerospace force. State-of-the-science advances are made in warfighter training, warfighter system interfaces, directed energy bioeffects, deployment and sustainment of warfighters in extreme environments, and understanding and shaping adversarial behavior. The Directed Energy Bioeffects Parameters project develops, demonstrates, and transitions technologies to predict, evaluate, and mitigate the effects of directed energy on personnel and mission performance, and exploits the offensive capabilities of directed energy systems. The Human Dynamics and Terrain Demonstration project develops, demonstrates, and transitions human-centric technologies to address processing, exploitation, and dissemination of intelligence, surveillance, and reconnaissance (ISR) capability needs. The Mission Effective Performance project develops, demonstrates, and transitions advanced training, simulation, mission rehearsal, and other performance-aiding methods and technologies to enhance warfighter readiness. The Warfighter Interfaces project develops, demonstrates, and transitions technologies to revolutionize the way airmen synergistically use Air Force systems, including autonomous machines and adaptive teams of airmen and machines. Efforts in this program have been coordinated through the Department of Defense (DoD) Science and Technology (S&T) Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	33.635	36.463	37.541	0.000	37.541
Current President's Budget	30.153	36.420	37.542	0.000	37.542
Total Adjustments	-3.482	-0.043	0.001	0.000	0.001
• Congressional General Reductions	-0.027	-0.043			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-0.960	0.000			
• Other Adjustments	-2.495	0.000	0.001	0.000	0.001

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>				Project (Number/Name) 635323 / <i>Directed Energy Bioeffects Parameters</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635323: <i>Directed Energy Bioeffects Parameters</i>	-	4.566	5.251	5.154	0.000	5.154	5.280	6.602	6.736	6.871	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops, demonstrates, and transitions technologies to predict, evaluate, and mitigate the effects of directed energy on personnel and mission performance, and exploits the offensive capabilities of directed energy systems. This project also develops the human components of the guidelines for testing, deployment, and protection from high power microwave and high energy laser systems and uses this information to enhance the effectiveness of these weapon systems in air, space, and cyber operations. The optical radiation bioeffects thrust develops and demonstrates technologies that counter optical threats, while exploiting optical systems for directed energy weapons applications. The radio frequency (RF) radiation bioeffects thrust develops and demonstrates technologies to assess RF bioeffects and collateral hazards from high power RF directed energy systems.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Optical Radiation Bioeffects	3.666	4.247	4.169
Description: Develop and demonstrate optical protective technologies for aircrew and ground personnel to provide protection against directed energy threats. Develop modeling capabilities to assess collateral hazards from high power directed energy laser systems.			
FY 2019 Plans: Mature integration of predictive models of bioeffects and protection in Air Force Research Laboratory (AFRL) level analysis architectures. Complete first end-to-end methodology for incorporation of probabilistic risk-based assessments for lasers in a collateral damage estimation toolset. Perform ground evaluation of prototype nuclear flash protection goggle to investigate technology compatibility with cockpit displays and airman performance requirements. Mature high-energy laser bioeffects and safety analysis tools through validation and verification and end-user evaluation for initial transition to major test range environments to help advance Department of Defense directed energy concepts. Apply matured technologies to support of Self Protect High Energy Laser Demonstrator(SHiELD) Advanced Technology Demonstration and AFRL Laser Weapons System Program during ground and flight test safety planning.			
FY 2020 Plans: Provide hazard analysis for Self Protect High Energy Laser Demonstrator (SHIELD) ATD flight safety reports. Complete safety analysis for advancing Department of Defense directed energy concepts for safety review and technical review boards. Continue updates to glare models that predict mission impact from bright light exposures with real-world background illumination using validation and verification experimental results. Continue evaluation of next generation of nuclear flash-blindness technologies and			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>	Project (Number/Name) 635323 / <i>Directed Energy Bioeffects Parameters</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
the impact on mission performance. Continue integration of optical radiation hazard and vision analysis and tools into Advanced Framework for Simulation, Integration and Modeling (AFSIM) architecture.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.078 million. Justification for the decrease is described in the plans above.				
Title: Radio Frequency Bioeffects		0.900	1.004	0.985
Description: Develop and demonstrate technologies to assess radio frequency (RF) bioeffects and collateral hazards from high power RF directed energy systems.				
FY 2019 Plans: Integrate high average power bio-heat dosimetry models into distributed simulation environments. Development of fast thermal gradient effects dosimetry validation models and continue effect model validation strategy. Develop high peak power assessment models and tools to address real world concerns. Further develop/refine high average power models and validation through use of empirical comparisons moving into finer resolution to include internal structures.				
FY 2020 Plans: Continue development and refinement of fast thermal gradient effects dosimetry validation models and continue effect model validation strategy. Continue development of high peak power assessment models and tools to address real world concerns. Investigate probability of injury from RF exposures through use of modeling and empirical comparisons. Continue integration of RF hazard analysis and tools into Advanced Framework for Simulation, Integration and Modeling (AFSIM) architecture.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.019 million. Justification for the decrease is described in the plans above.				
Accomplishments/Planned Programs Subtotals		4.566	5.251	5.154
C. Other Program Funding Summary (\$ in Millions)				
N/A				
Remarks				
D. Acquisition Strategy				
N/A				
E. Performance Metrics				
Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>				Project (Number/Name) 635324 / <i>Human Dynamics and Terrain Demonstration</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635324: <i>Human Dynamics and Terrain Demonstration</i>	-	5.122	5.408	5.886	0.000	5.886	6.001	7.446	7.597	7.749	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops, demonstrates, and transitions technologies to identify human threats within the air, space, and cyber domains. These technologies will enhance Air Force capabilities in intelligence, surveillance and reconnaissance (ISR), layered sensing, autonomous and adaptive decision-making systems, decision aids for computer network attack/defense/support, ISR force development and training, cross-cultural communication, human-centric exploitation of measurement and signatures intelligence, and advanced molecular diagnostic methodologies to assess airman performance.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Human Analyst Augmentation	3.507	3.771	4.104
Description: Develop and demonstrate human-centered design processes and operational tools that optimize ISR information exploitation and analysis.			
FY 2019 Plans: Transition speech to text technologies to Distributed Ground System Special Operations Forces (DGS-SOF). Preparing for transition of multi-intelligence analysis tools and airman-machine collaboration technologies to Air Force Distributed Common Ground System (AF-DCGS).			
FY 2020 Plans: Develop and transition multi-intelligence analysis tools and airman-machine collaboration technologies to Air Force Distributed Common Ground System (AF-DCGS) via enhanced research Content Management System (ICMS) and DCGS Open-Architecture. Prepare to transition global situation-awareness and decision-making capabilities to Air and Space Operations Center (AOC) and multi-domain operations centers.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.333 million. Justification for the increase is described in the plans above.			
Title: Human Trust and Interaction	1.615	1.637	1.782
Description: Develop and demonstrate machine translation and speech-to-text tools to support the span of Air Force mission areas including ISR and cyber operations.			
FY 2019 Plans:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>	Project (Number/Name) 635324 / <i>Human Dynamics and Terrain Demonstration</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Develop initial context awareness of deep neural networks for improving automatic speech recognition and machine translation algorithms for Intelligence Surveillance Reconnaissance (ISR) analyst applications. <i>FY 2020 Plans:</i> Continue to advance and mature deep neural networks to improve automatic speech recognition, machine translation, and natural language processing technologies as applied to multimedia information. <i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$0.145 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	5.122	5.408	5.886

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>				Project (Number/Name) 635325 / <i>Mission Effective Performance</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635325: <i>Mission Effective Performance</i>	-	5.984	6.795	6.930	0.000	6.930	7.069	7.213	7.358	7.505	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops, demonstrates, and transitions advanced training, simulation, mission rehearsal, and other performance-aiding methods and technologies to enhance warfighter readiness. This project also develops advanced methods and technologies to enable interactive live, virtual, and constructive (LVC) environments for performance-aiding methods and technologies. Focus areas include integrated high-fidelity weapon systems training technologies for air, space, and cyber; tailored immersive simulation environments for airmen at the tactical and operational levels; and incorporation of performance assessment and feedback tools. These methods and technologies facilitate the development of mission-essential competencies.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Continuous Learning	5.984	6.795	6.930
Description: Develop and demonstrate secure, persistent, and standardized LVC training enterprise. Utilize modeling capabilities for technology demonstration efforts focused on developing software-based tools for training that would replace human instructors. This enables more efficient mission execution training in an LVC environment.			
FY 2019 Plans: Continue development and demonstration of sharable content across domain for airman machine team and multi-domain command and control. Define data and content standards and establish warehouse for multiple domain performance data to enable proficiency-based training. Test and evaluate proficiency-based training at an operational unit. Increase after action review data visualization for real-time lessons learned and training effectiveness. Create interfaces permitting alignment of learner/operator engagement in learning contexts and resulting mission readiness and performance outcomes in operational contexts. Perform assessments and evaluations of common range and simulation architecture technologies for Live, Virtual, and Constructive training capabilities.			
FY 2020 Plans: Continue development of proficiency-based training metrics and assessments in operational contexts. Continue multi-domain operations training development and demonstration. Continue field evaluations for performance-based after action review visualization tools in unit-level and Red Flag-Level training and rehearsal. Continue assessments and evaluations of common range and simulation architecture technologies for Live, Virtual, and Constructive training capabilities. Create methods for rapid development of mission-oriented software agent applications. Develop contested degraded operations environment for multi-domain operations training and rehearsal.			
FY 2019 to FY 2020 Increase/Decrease Statement:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>	Project (Number/Name) 635325 / <i>Mission Effective Performance</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$0.135 million. Justification for the increase is described in the plans above.			
Accomplishments/Planned Programs Subtotals	5.984	6.795	6.930

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>				Project (Number/Name) 635327 / <i>Warfighter Interfaces</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635327: <i>Warfighter Interfaces</i>	-	14.481	18.966	19.572	0.000	19.572	17.887	15.808	16.127	16.449	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops, demonstrates, and transitions technologies to revolutionize the way airmen optimize the capabilities of Air Force systems, including autonomous machines and adaptive teams of Airmen and machines. Improvements in the presentation of operational information to the community of users, from the system operator to the commander, must be developed in step with advancements in the acquisition, storage, and retrieval of information. This project provides the advances in understanding of human cognitive abilities, as well as the utilization of human interfaces, multisensory fusion, high-resolution image displays, and three-dimensional (3D) audio to customize communications and enhance shared understanding across a diverse user community in air, space, and cyber for maximum situational awareness.

B. Accomplishments/Planned Programs (\$ in Millions)

<p>Title: Battlespace Acoustics</p> <p>Description: Demonstrate ability to forecast acoustic profiles for any atmospheric/terrain condition. Demonstrate technologies to enhance the battlefield Airman's situational awareness through wearable interfaces.</p> <p>FY 2019 Plans: Continue 3D audibility modeling research for special operations aviation focusing on effects of atmospheric, terrain, and psychoacoustic performance, and continue development/refinement of advanced interfaces for real-time interaction with acoustic models of listening environments. Continue conducting usability testing and employing advanced engineering methodologies for rapid prototyping, testing and seamless integration of innovative technologies into tactical ensembles supporting Battlefield Airmen and Para-rescue operations. Continue to transition enhanced, man-wearable communication systems, mobile interfaces, and physiological sensors to enhance situation awareness, improve training, and support real-time battlespace monitoring for dismounted operators.</p> <p>FY 2020 Plans: Validate understanding of limitations in human auditory perception to build acoustic countermeasures to control perception of special aviation acoustic signatures. Continue to develop 3D audibility models for special operations aviation through the exploitation of high-fidelity acoustic measurements focusing on effects of atmospheric and terrain. Conduct usability testing and employ advanced engineering methodologies for rapid prototyping, testing and seamless integration of man-wearable communication systems, mobile interfaces, and physiological sensors into tactical ensembles supporting Battlefield Airmen and Para-rescue operations. Expected transitions include a suite of e-textile solutions eliminating conventional cabling through-out tactical vests, an integrated/wireless hub transfer of power and data to body-worn peripheral devices, and an array rapidly developed technology in response to urgent needs of dismounted operators.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement:</p>	FY 2018	FY 2019	FY 2020
	3.644	4.712	4.862

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603456F / <i>Human Effectiveness Advanced Technology Development</i>	Project (Number/Name) 635327 / <i>Warfighter Interfaces</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
FY 2020 increased compared to FY 2019 by \$0.150 million. Justification for the increase is described in the plans above.				
Title: Human Role in Semiautonomous Systems		10.837	14.254	14.710
Description: Develop and demonstrate an integrated human-centered interface for Human-Machine Teaming (HMT) scenarios to control multiple Remotely Piloted Aircraft (RPA) that have various levels of autonomy and that optimize net-centric information flow. Develop and demonstrate manned/unmanned interaction and team concepts for tactical environments.				
FY 2019 Plans: Flight demonstrate airman-directed control and management of multiple unmanned tactical behaviors. Develop and integrate decision support and embedded intelligent agent capabilities to assess and reason about manned-unmanned team performance and overall mission effectiveness. Demonstrate adaptive human-machine interfaces and task allocation methods in virtual and live tests. Initiate matrixed cooperative teams in networked simulation environments.				
FY 2020 Plans: Flight demonstrate airman-directed control and management of multiple unmanned tactical behaviors involving increasingly complex mission sets (e.g., dynamic mission objectives, high uncertainty, unreliable communication links). Demonstrate integrated decision support and embedded intelligent agent capabilities to assess and reason about manned-unmanned team performance and overall mission effectiveness. Continue to demonstrate adaptive human-machine interfaces and task allocation methods in virtual and live tests in operationally relevant environments. Demonstrate teaming concepts and technologies among cooperative human-machine teams in networked simulation environments.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.456 million. Justification for the increase is described in the plans above.				
Accomplishments/Planned Programs Subtotals		14.481	18.966	19.572
C. Other Program Funding Summary (\$ in Millions) N/A				
Remarks				
D. Acquisition Strategy N/A				
E. Performance Metrics Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.				

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	157.676	204.756	225.817	0.000	225.817	206.783	215.366	227.204	232.407	Continuing	Continuing
63670A: <i>Weapon Technology Development</i>	-	82.406	105.132	57.895	0.000	57.895	51.830	74.854	76.367	77.895	Continuing	Continuing
63670B: <i>Weapon Concept Development</i>	-	75.270	99.624	167.922	0.000	167.922	154.953	140.512	150.837	154.512	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops, integrates, and demonstrates advance ordnance and guidance technologies for air-launched conventional weapons. The effort focuses on conventional ordnance component technologies such as war-heads, fuzes, and explosives, as well as munition guidance component technologies such as navigation and control systems and seekers. Technologies to be developed, demonstrated, and integrated into system concepts will address blast, fragmentation, penetration, low collateral damage, variable depth/location fuzing, precise guidance, and high-performance and insensitive explosives. Efforts in this program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	167.415	194.981	231.292	0.000	231.292
Current President's Budget	157.676	204.756	225.817	0.000	225.817
Total Adjustments	-9.739	9.775	-5.475	0.000	-5.475
• Congressional General Reductions	0.000	-0.225			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	10.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	5.800	0.000			
• SBIR/STTR Transfer	-3.309	0.000			
• Other Adjustments	-12.230	0.000	-5.475	0.000	-5.475

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 63670A: *Weapon Technology Development*

Congressional Add: *Program increase - rotary launcher development*

	FY 2018	FY 2019
	0.000	10.000
Congressional Add Subtotals for Project: 63670A	0.000	10.000
Congressional Add Totals for all Projects	0.000	10.000

Change Summary Explanation

Decrease in FY 2018 of \$12.230 million in Other Adjustments is due to realignment of funds to PE 0602212F, to support Research and Development Projects, 10 U.S.C. Section 2358.

Increase in FY 2018 of \$5.800 million due reprogramming action for hypersonic weapon technology.

Decrease in FY 2020 due to realignment of \$5.475 million from PE 0603601, Conventional Weapons Technology, to PE 0602602F, Conventional Munitions, for hypersonic weapon component technology maturation.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>				Project (Number/Name) 63670A / <i>Weapon Technology Development</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
63670A: <i>Weapon Technology Development</i>	-	82.406	105.132	57.895	0.000	57.895	51.830	74.854	76.367	77.895	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops, matures, assesses, and demonstrates advanced/innovative ordnance and guidance component and subsystem technologies for air-launched conventional weapons. The project focuses on maturation of advanced explosives, fuzes, warheads, sub-munitions, and weapon airframes, carriage and dispensing; as well as innovative munition seekers, weapon aerodynamics, navigation and control, and guidance subsystem integration/simulation.

B. Accomplishments/Planned Programs (\$ in Millions)

<p>Title: Ordnance Technologies</p> <p>Description: Develop and demonstrate integrated ordnance technologies to improve conventional air-delivered munitions. Specific technical areas of focus include energetic materials, fuze technology, warhead sciences, and modeling and simulation tools.</p> <p>FY 2019 Plans: Continue to demonstrate distributed, embedded fuzing concepts for close-controlled strike, area attack, and penetration applications (layer counting at high speed), including assessing long-term safety, survivability, and functionality. Continue development of ordnance technologies to allow tailored lethality by controlling weapon fragmentation. Continue to mature ordnance technologies for rapid transition into high-speed strike weapon concepts, collecting complex arena test data for implementation into lethality modeling and simulation tools. Continue to develop test capabilities and high fidelity analysis tools into higher level engineering and fast-running models to enable the war-fighter to make more accurate weaponeering choices. Continue to develop ordnance technologies/methodologies for high-speed impact and functional defeat. Continue research for distributed and multi-point fuzing concepts to reduce the logistics tail necessary for future and fielded munitions systems, as well as safe and arm functions. Continue research into armament systems for Special Operations applications. Continue to conduct lethality analyses for air-to-air weaponry, and improve lethality and survivability tools at the mesoscale and micro-scale. Continue to mature research on distributed, collaborative, cooperative effects munitions technologies. Initiate multiple-hit target demonstration against hard and deeply buried targets. Initiate the development high fidelity test capabilities and analysis tools to evaluate ordnance technologies in relevant environments. Initiate the development of improved material models and develop further joint kinetic/directed energy common target models. Initiate development of models for progressive collapse, multiple point initiation, secondary debris and others.</p> <p>FY 2020 Plans:</p>	FY 2018	FY 2019	FY 2020
	45.535	49.940	29.582

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>	Project (Number/Name) 63670A / <i>Weapon Technology Development</i>

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
<p>Complete characterization of weapon effects for distributed multi-point detonation fuze technology including safe and arm functions. Complete multiple-hit target demonstration against hard and deeply buried targets. Continue demonstration of distributed, embedded fuzing concepts for close-controlled strike, area attack, and penetration applications (layer counting at high speed), including assessing long-term safety, survivability, and functionality. Continue development of ordnance technologies to allow tailored lethality by controlling weapon fragmentation. Continue to mature ordnance technologies for rapid transition into high-speed strike weapon concepts, collecting complex arena test data for implementation into lethality modeling and simulation tools. Continue to develop test capabilities and high fidelity analysis tools into higher level engineering and fast-running models to enable the war-fighter to make more accurate weaponeering choices. Continue to develop ordnance technologies/methodologies for high-speed impact and functional defeat. Continue research into armament systems for Special Operations applications. Continue to conduct lethality analyses for air-to-air weaponry, and improve lethality and survivability tools at the mesoscale and micro-scale. Continue to mature research on distributed, collaborative, cooperative effects munitions technologies. Continue the development high fidelity test capabilities and analysis tools to evaluate ordnance technologies in relevant environments. Continue development of improved material models and develop further joint kinetic/directed energy common target models. Continue to develop models for progressive collapse, multiple point initiation, secondary debris and others.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$20.358 million. Funding decreased due to the completion of ordnance-related testing associated with multiple-hit weapon demonstrations, reduction of conformal warhead research, and completion of distributed embedded fuzing demonstration.</p>			
<p>Title: Guidance Technologies</p> <p>Description: Develop guidance technologies to improve the precision, controlled lethality, and flexibility of conventional, air-delivered munitions. Specific technical areas include precision navigation and terminal seekers.</p> <p>FY 2019 Plans: Continue hardware-in-the-loop and software-in-the-loop characterization air-to-air and air-to-ground guidance and control technologies. Continue integration of hardware-in-the-loop, software-in-the-loop, and other modeling and simulation (M&S) technologies for the demonstration of open architecture, high-speed, cooperative, and modular weapon munition concepts. Initiate the development of advanced modular and service oriented weapon architectures. Continue the design and development of seeker subsystem prototypes for platform self-defense. Continue development of advanced, high-resolution infrared (IR) scene projectors, distributed simulation concepts, software defined radio frequency (RF) test chamber, scene generation, mission, engagement, campaign level simulations, and panoramic infrared dome technologies. Continue to develop technologies for precision navigation of weapons in Global Positioning System (GPS)-denied scenarios. Continue to mature and integrate advanced carriage and release concepts and sub-systems. Continue to refine and complete fabrication of M&S center and initiate processes to enable simultaneous multi-level security M&S activities. Continue lethality analyses of in-house and Air Force</p>	36.871	45.192	28.313

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>	Project (Number/Name) 63670A / <i>Weapon Technology Development</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>weapon concepts. Initiate the design of hotter/faster IR panoramic projector for advanced seeker testing. Initiate the integration of higher fidelity constructive analysis tools with engagement and mission level M&S.</p> <p>FY 2020 Plans: Complete hardware-in-the-loop and software-in-the-loop characterization air-to-air and air-to-ground guidance and control technologies. Continue integration of hardware-in-the-loop, software-in-the-loop, and other Modeling and Simulation technologies for the demonstration of open architecture, high-speed, cooperative, and modular weapon munition concepts. Continue the design and development of seeker subsystem prototypes for platform self-defense. Continue development of advanced, high-resolution infrared scene projectors, distributed simulation concepts, software defined Radio Frequency test chamber, scene generation, mission, engagement, campaign level simulations, and panoramic infrared dome technologies. Continue to develop technologies for precision navigation of weapons in Global Positioning System-denied scenarios. Continue to mature and integrate advanced carriage and release concepts and sub-systems. Complete fabrication of Modeling and Simulation center and initiate processes to enable simultaneous multi-level security Modeling and Simulation activities.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$16.879 million. Funding decreased due to planned completion of multi-platform autonomy demonstration flight test, reduction of high-speed weapon component guidance research, and conclusion of modular weapon concept activities.</p>			
Accomplishments/Planned Programs Subtotals	82.406	95.132	57.895

	FY 2018	FY 2019
Congressional Add: Program increase - rotary launcher development	0.000	10.000
FY 2018 Accomplishments: N/A		
FY 2019 Plans: Conduct Congressionally directed efforts		
Congressional Adds Subtotals	0.000	10.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>	Project (Number/Name) 63670A / <i>Weapon Technology Development</i>

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>				Project (Number/Name) 63670B / <i>Weapon Concept Development</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
63670B: <i>Weapon Concept Development</i>	-	75.270	99.624	167.922	0.000	167.922	154.953	140.512	150.837	154.512	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops, refines, integrates, demonstrates, and assesses ordnance and guidance technologies to reduce risk for potential air-launched conventional weapons acquisitions. The project concentrates in two effort areas, Air-to-Air Concept Development and Air-to-Ground Concept Development. The project focuses on risk reduction of advanced explosives, fuzes, warheads, sub-munitions, and weapon airframes, carriage and dispensing; as well as innovative munition seekers, weapon aerodynamics, navigation and control, and guidance subsystem integration/simulation.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Air-to-Air Concept Development	20.098	30.188	81.207
Description: Mature, integrate, and demonstrate air-to-air weapon components and systems (ordnance, guidance, and carriage and release technologies) to demonstrate war-fighter capability.			
FY 2019 Plans: Continue to demonstrate weapon integration concepts for air target engagement. Continue planning and technology risk reduction for weapon concepts responsive to the 2030 timeframe threat environment (including air-to-air weapons for both offensive and defensive purposes). Continue to test prototype propulsion systems to demonstrate attributes to meet next-generation air-to-air weapon requirements. Continue to conduct lethality studies to enable design of small form factor self-defense of an air platform. Continue to develop preliminary design of air-to-air weapon concepts for sixth generation platforms. Continue to conduct wind-tunnel and limited flight experiments to characterize air-to-air maneuverability, range, and guidance and control for sixth generation weapon concept. Continue to conduct ground and arena tests of advanced weapons experimental-carriages for sixth generation weapon concept and prepare for flight worthiness testing. Continue to mature simulation architectures to assess the trades and synergies between kinetic and directed energy weapons. Continue to incorporate higher fidelity methodologies into systems level analysis including joint weapons effectiveness. Initiate highly agile airframe flight test planning.			
FY 2020 Plans: Continue developing the technology trade space to enable air-to-air weapons with robust capability in the future-years threat environment, including technologies for efficient propulsion, high lethality, efficient flight/high-agility, miniaturization, and cost and risk reduction for both offensive and defensive purposes. Continue to develop and test prototype propulsion systems with flexibility to enable more adaptable next generation air-to-air weapons. Continue to conduct lethality studies to enable design of small form factor warheads lethal against the future plus target set. Continue to develop preliminary design of air-to-air weapon concepts for sixth generation platforms. Continue to document missile flight dynamics trade space and conduct wind-tunnel			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>	Project (Number/Name) 63670B / <i>Weapon Concept Development</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>experiments to characterize airframes and validate aerodynamic codes leading to development of highly maneuverable and efficient missiles to counter advanced targets, and improve persistence and survivability of future platforms. Continue to conduct ground and arena tests of advanced weapons experimental-carriages for sixth generation weapon concept and prepare for flight worthiness testing. Continue to mature simulation architectures to assess the trades and synergies between kinetic and directed energy weapons. Continue to incorporate higher fidelity methodologies into systems level analysis including joint weapons effectiveness and perform experiments with small warheads to obtain data for lethality analysis and validate designs. Continue to plan and execute highly agile airframe ground tests and integrated sub-system experimentation. Initiate planning for major subsystem component tests to verify baseline performance for future counter-air application and platform integration.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$51.019 million. Funding increased due to significant expansion of test and experimentation activity related to counter-air technology development, miniaturization of weapon and munition component technology and subsystems, multiple ground and environmental tests, modeling and data reduction, and supporting analysis.</p>			
<p>Title: Air-to-Ground Concept Development</p> <p>Description: Mature, integrate, and demonstrate air-to-ground weapon components and systems (ordnance, guidance, and carriage and release technologies) to demonstrate war-fighter capability.</p> <p>FY 2019 Plans: Complete to investigate concepts for cooperative control /multi-hit of small weapons to produce scalable effects to increase the capacity and capability of fifth generation aircraft. Complete competitive contractor processes to develop flying experimental concepts of the subsonic, standoff, low cost cruise missile capability. Continue to conduct relevant long range strike weapon technology demonstrations to reduce risk for potential follow-on acquisition programs, and finalize system detailed design for flying hypersonic munition demonstrator flight. Continue the development of munition concepts to incorporate technologies for carriage and terminal impact at high speed. Continue planning and technology risk reduction including demonstration and initial flight testing for weapons concepts responsive to the future-year threats timeframe threat environment (including hypersonic and cooperative/collaborative concepts). Continue to mature simulation architectures to assess the trades and synergies between kinetic and directed energy weapons. Continue to incorporate higher fidelity methodologies into systems level analysis including joint weapons effectiveness and to apply methodology to support future air dominance analysis. Continue to investigate kinetic/ non-kinetic payloads, networking, seeker, fuze, and defense countermeasures technology for hypersonic applications. Initiate system integration of algorithms and radios onto pathfinder weapon system to enable synchronized collaborative weapon effects.</p> <p>FY 2020 Plans: Complete low-cost cruise missile/small engine flight test demo. Continue to conduct relevant long range strike weapon technology demonstrations to reduce risk for potential follow-on acquisition programs, and finalize system detailed design for</p>	55.172	69.436	86.715

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603601F / <i>Conventional Weapons Technology</i>	Project (Number/Name) 63670B / <i>Weapon Concept Development</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>flying hypersonic munition demonstrator flight. Continue the development of munition concepts to incorporate technologies for carriage and terminal impact at high speed. Continue planning and technology risk reduction including demonstration and initial flight testing for weapons concepts responsive to the future-year time-frame threat environment (including hypersonic and cooperative/collaborative concepts). Continue to mature simulation architectures to assess the trades and synergies between kinetic and directed energy weapons. Continue to incorporate higher fidelity methodologies into systems level analysis including joint weapons effectiveness and to apply methodology to support future air dominance analysis. Continue to investigate kinetic/non-kinetic payloads, seeker, and fuze technology for hypersonic applications. Continue system integration of algorithms and software defined radios onto pathfinder weapon system to enable synchronized collaborative weapon effects.</p> <p><i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$17.279 million. Funding increased due to significant development and integration of hardware, software, and modeling capability to support next-generation munitions and weapons effects.</p>			
Accomplishments/Planned Programs Subtotals	75.270	99.624	167.922

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603605F / <i>Advanced Weapons Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	42.322	43.368	37.404	0.000	37.404	30.971	32.217	42.641	43.566	Continuing	Continuing
633151: <i>High Power Solid State Laser Technology</i>	-	30.572	28.200	19.244	0.000	19.244	13.040	13.355	23.351	23.857	Continuing	Continuing
633152: <i>High Power Microwave Development and Integration</i>	-	11.750	15.168	18.160	0.000	18.160	17.931	18.862	19.290	19.709	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program provides for the development, integration, demonstration, and detailed assessment of directed energy (DE) weapon technologies for potential application on Air Force platforms. These include high energy laser (HEL), high power microwaves (HPM), and other unconventional weapon generation and transmission technologies, which can support a wide range of Air Force applications. The program develops a corresponding susceptibility, vulnerability, and lethality database for directed energy weapons. This program also develops laser-enabled atmospheric-compensated optical imaging for space situational awareness (SSA). Efforts in this program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603605F / <i>Advanced Weapons Technology</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	45.502	43.368	37.467	0.000	37.467
Current President's Budget	42.322	43.368	37.404	0.000	37.404
Total Adjustments	-3.180	0.000	-0.063	0.000	-0.063
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.515	0.000			
• Other Adjustments	-1.665	0.000	-0.063	0.000	-0.063

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603605F / <i>Advanced Weapons Technology</i>	Project (Number/Name) 633151 / <i>High Power Solid State Laser Technology</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
633151: <i>High Power Solid State Laser Technology</i>	-	30.572	28.200	19.244	0.000	19.244	13.040	13.355	23.351	23.857	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project provides for the development, integration, demonstration, and detailed technical assessment of high energy laser (HEL) devices, advanced imaging and beam control technologies needed for applications such as force protection, force application, precision engagement, and aircraft self-protection. Laser system concept assessments to include vulnerability assessments and target effect testing are performed. This project also exploits the synergy between high energy laser beam control and advanced optical imaging for space situational awareness (SSA).

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: High Energy Laser/Beam Control	30.572	27.624	18.738	0.000	18.738
Description: Develop and demonstrate advanced beam control technologies, integrated laser systems, and aircraft self-protection laser technologies. Demonstrate beam control components integrated with high energy lasers (HEL) for Air Force utility.					
FY 2019 Plans: Integrate a low power laser system into a pod for Phase 1 aircraft self-protect demonstration. Begin integration of a medium power laser system into the pod for Phase 2 aircraft self-protect demonstration. Continue with integration of the laser control subsystem for directing the laser onto the target for aircraft self-protect demonstration. Continue development of the ground support and aircraft interface.					
FY 2020 Base Plans: Continue to demonstrate the integrated low power laser system in a pod for Phase 1 aircraft self-protect demonstration. Continue integration of a medium power laser system into the pod for Phase 2 aircraft self-protect demonstration. Complete integration of the laser control subsystem for directing the laser onto the target for aircraft self-protect demonstration. Complete development of ground support and aircraft interface. Complete first amplifier prototype for ultra-compact laser and transition into laser subsystem development.					
FY 2020 OCO Plans: Not Applicable					
FY 2019 to FY 2020 Increase/Decrease Statement:					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force				Date: February 2019	
Appropriation/Budget Activity 3600 / 3		R-1 Program Element (Number/Name) PE 0603605F / <i>Advanced Weapons Technology</i>		Project (Number/Name) 633151 / <i>High Power Solid State Laser Technology</i>	
B. Accomplishments/Planned Programs (\$ in Millions)					
FY 2020 decreased compared to FY 2019 by \$8.886 million. Funding decreased due to re-scoping of the Laser Subsystem Development activity.					
Title: Optical Space Situational Awareness and Satellite Vulnerability					
Description: Mature development of laser-enabled, long-range, electro-optical technologies that enable 24/7 ground-based optical space situational awareness (SSA) delivering characterization results on tactical timelines. Develop and demonstrate technologies that accurately assess the vulnerability of blue satellite systems to lasers. Manage and operate research assets in support of development, demonstration, and integration of ground-based optical space situational awareness (SSA) technologies.					
FY 2019 Plans: Develop full-dark real-time high-spatial resolution optical imaging of near-earth space objects using laser illumination. Initiate system requirements for demonstrating real-time daylight imaging of near-earth objects using laser-enabled atmospheric compensation.					
FY 2020 Base Plans: Continue development of full-dark real-time high-spatial resolution optical imaging of near-earth space objects using laser illumination. Complete system requirements for demonstrating real-time daylight imaging of near-earth objects using laser-enabled atmospheric compensation.					
FY 2020 OCO Plans: Not Applicable					
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased by \$0.070 million compared to FY 2019. Justification of decrease in plans above.					
Accomplishments/Planned Programs Subtotals					
	0.000	0.576	0.506	0.000	0.506
	30.572	28.200	19.244	0.000	19.244
C. Other Program Funding Summary (\$ in Millions)					
N/A					
Remarks					
D. Acquisition Strategy					
N/A					

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603605F / <i>Advanced Weapons Technology</i>	Project (Number/Name) 633151 / <i>High Power Solid State Laser Technology</i>

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603605F / <i>Advanced Weapons Technology</i>	Project (Number/Name) 633152 / <i>High Power Microwave Development and Integration</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
<i>633152: High Power Microwave Development and Integration</i>	-	11.750	15.168	18.160	0.000	18.160	17.931	18.862	19.290	19.709	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project develops and demonstrates high power microwave (HPM) and other unconventional weapon generation and transmission technologies that support a wide range of Air Force missions such as air base defense or the damage/destruction of an adversary's electronic infrastructure. It also provides inputs to the susceptibility, vulnerability, and lethality databases used across the Department of Defense (DoD) to understand thresholds for scalable effects.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Title: High Power Microwave Technologies	11.750	15.168	18.160	0.000	18.160
Description: Develop and evaluate high power microwave (HPM) and other unconventional weapon technologies for various platforms, including aerial, for applications such as counter-electronics. Develop and evaluate high power microwave technologies for non-kinetic and counter-electronic weapon applications.					
FY 2019 Plans: Develop a class of reusable, multi-pulse, multi-target counter-electronics payloads capable of being hosted in various advanced platforms. Characterize, model, test and evaluate current and projected blue directed energy threats on current red assets. Design and develop the high power microwave (HPM) payload for the joint flight demonstration with the Navy. Conduct environmental testing of the high power microwave (HPM) missiles.					
FY 2020 Base Plans: Test a class of reusable, multi-pulse, multi-target counter-electronics payloads capable of being hosted in various advanced platforms. Continue to characterize, model, test and evaluate current and projected blue directed energy threats on current red assets. Develop and test the high power microwave payload for the joint flight demonstration with the Navy. Design agile waveform high power sources.					
FY 2020 OCO Plans: Not Applicable					
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased by \$2.992 million compared to FY 2019. Funding increased due to additional Joint Navy-Air Force High Power Microwave demonstration activities.					
Accomplishments/Planned Programs Subtotals	11.750	15.168	18.160	0.000	18.160

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603605F / <i>Advanced Weapons Technology</i>	Project (Number/Name) 633152 / <i>High Power Microwave Development and Integration</i>

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity					R-1 Program Element (Number/Name)							
3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>					PE 0603680F / <i>Manufacturing Technology Program</i>							
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	63.224	65.760	43.116	0.000	43.116	44.416	45.943	47.002	48.051	Continuing	Continuing
635280: <i>Manufacturing Technologies</i>	-	63.224	65.760	43.116	0.000	43.116	44.416	45.943	47.002	48.051	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program executes technical programs to maintain and develop an affordable and reliable industrial base and manufacturing capability that will be responsive to warfighter needs. The program develops and improves manufacturing technologies and processes to enable cost reduction, improve component and system quality, and enhance industrial capability. Value stream modifications and manufacturing throughput improvements are effected to shorten cycle times of weapon systems during design, development, production and sustainment. Manufacturing Technologies objectives are conducted through industrial partnerships which enable the demonstration of manufacturing technologies for existing weapon system upgrades and/or for new warfighter systems. Efforts in the program have been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.

This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)	R-1 Program Element (Number/Name) PE 0603680F I Manufacturing Technology Program
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	46.450	42.025	43.116	0.000	43.116
Current President's Budget	63.224	65.760	43.116	0.000	43.116
Total Adjustments	16.774	23.735	0.000	0.000	0.000
• Congressional General Reductions	-0.040	-0.065			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	18.600	23.800			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.786	0.000			
• Other Adjustments	0.000	0.000	0.000	0.000	0.000

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 635280: *Manufacturing Technologies*

Congressional Add: *Program Increase*

Congressional Add: *Program increase - F-35 Battery Technology*

Congressional Add: *Program increase - Materials Development Research*

Congressional Add: *Program Increase - Modeling Technology for Small Turbine Engines*

Congressional Add Subtotals for Project: 635280

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	9.725	0.000
	8.364	9.800
	0.000	10.000
	0.000	4.000
	18.089	23.800
	18.089	23.800

C. Accomplishments/Planned Programs (\$ in Millions)

Title: Sustainment Manufacturing Technologies

Description: Develop and transition pervasive affordability and producibility technologies for the sustainment of weapons systems and processes.

FY 2019 Plans:

Continue development of cost effective conventional production and special material repair technologies to enable affordable sustainment of aircraft systems. Continue agile sustainment and automation manufacturing technology development for depot maintenance.

FY 2020 Plans:

	FY 2018	FY 2019	FY 2020
	12.006	11.749	12.072

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>		R-1 Program Element (Number/Name) PE 0603680F / <i>Manufacturing Technology Program</i>		
C. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
Advance high demand specialized manufacturing technologies to develop cost effective conventional production and special material repair technologies to enable affordable sustainment of aircraft systems. Align distributed advanced manufacturing techniques and concepts for agile sustainment and automation technology development for depot maintenance and flight line repair efficiency. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.323 million. Justification for the increase is described in the plans above.				
Title: Advanced Manufacturing Technologies Description: Develop and transition affordable advanced manufacturing technologies for weapons systems. FY 2019 Plans: Continue development and demonstration of agile manufacturing capabilities for more affordable advanced turbine engine propulsion technologies, Intelligence, Surveillance, Reconnaissance (ISR) and communications technologies, transparent ceramics producibility, and the producibility of air armaments. Continue development of agile manufacturing applications and structures affordability with a focus on low cost attritable aircrafts and open pod architecture. Continue to develop manufacturing capabilities for producibility and affordability of aerospace structures, and hypersonics. FY 2020 Plans: Continue to refine the development and demonstrate advanced agile manufacturing and repair capabilities for more affordable and increased availability of advanced turbine engine propulsion technologies, ISR and communications technologies, transparent ceramics producibility, and the producibility of air armaments. Continue and refine development of high demand distributed agile manufacturing applications and structures affordability with a focus on low cost attritable aircrafts and open pod architecture. Transition successful technologies. Continue the development and demonstrate manufacturing capabilities for producibility and affordability of aerospace structures, and hypersonics. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.833 million. Justification for the increase is described in plan above.		33.129	30.211	31.044
Accomplishments/Planned Programs Subtotals		45.135	41.960	43.116
		FY 2018	FY 2019	
Congressional Add: Program Increase		9.725	0.000	

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603680F / <i>Manufacturing Technology Program</i>
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	FY 2018	FY 2019
FY 2018 Accomplishments: Conducted Congressionally directed efforts. FY 2019 Plans: Not Applicable		
Congressional Add: Program increase - F-35 Battery Technology FY 2018 Accomplishments: Conducted Congressionally directed efforts. FY 2019 Plans: Conduct Congressionally directed efforts.	8.364	9.800
Congressional Add: Program increase - Materials Development Research FY 2018 Accomplishments: Not Applicable FY 2019 Plans: Conduct Congressionally directed efforts.	0.000	10.000
Congressional Add: Program Increase - Modeling Technology for Small Turbine Engines FY 2018 Accomplishments: Not Applicable FY 2019 Plans: Conduct Congressionally directed efforts.	0.000	4.000
Congressional Adds Subtotals	18.089	23.800

D. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	45.481	60.017	56.414	0.000	56.414	56.746	60.569	62.299	63.968	Continuing	Continuing
635319: <i>Anticipatory OPS Intent and Response</i>	-	5.709	6.099	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11.808
635320: <i>Assured Worldwide Connectivity</i>	-	12.831	21.658	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	34.489
635321: <i>C4I Battlespace Dev and Demo</i>	-	5.429	11.242	36.303	0.000	36.303	35.564	37.095	38.153	39.173	Continuing	Continuing
635322: <i>Knowledge Management and Computing</i>	-	3.299	3.782	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.081
635329: <i>Cyber Battlespace Dev & Demo</i>	-	18.213	17.236	20.111	0.000	20.111	21.182	23.474	24.146	24.795	Continuing	Continuing

A. Mission Description and Budget Item Justification

This program develops and demonstrates Air Force enterprise-centric information technologies for the warfighter. The Anticipatory Operations Intent and Response project develops the technologies for dynamic planning and execution with the accuracy, fidelity, and timeliness needed to dominate the battlespace. The Assured Worldwide Connectivity project provides advanced net-enabled architectures and communications technologies in support of global military operations, including a secure information grid for worldwide information exchange of near-real-time multimedia (i.e., voice, data, video, and imagery) information. In addition, this project develops and demonstrates advanced optical networking and communications for Air Force air and space-based information exchange on and between platforms. These optical networks will be rapidly deployable, mobile, interoperable, and seamless between Air and Space Operations Centers (AOCs) and air and space-based platforms either en route or in theater. This project also provides tools and applications leading to the development and integration of cyber deterrence technologies resulting in a strategic capability of cyber dominance within the secure information grid. The Global Battlespace Awareness project develops, integrates, and demonstrates advanced technologies to achieve comprehensive net-centric operations and total battlespace awareness by using and exploiting information from all sources. The Knowledge Management and Computing project develops the technology applications that will provide for a secure, tailored, seamless exchange of information among producers, consumers, and managers of information relevant to a particular community of interest (COI). The project also provides the development of interactive and real-time computing technologies that greatly improve the usability of high-performance computing for the exchange, utilization, and management of information in the enterprise. The Cyber Battlespace Development and Demonstration project develops the ability to deliver sovereign options in cyberspace through the development and integration of cyber attack, cyber defense, and cyber support technologies for a strategic capability of cyber dominance.

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. Operational agility will require flexibility (manifested as multi-domain operations), speed (manifested as superior decision speed), coordination (manifested as dynamic command and control), balance (manifested as presenting a balanced capability mix), and strength (manifested as performance-optimized teams). In order to enable operational agility, this program will

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	
<p>begin to shape future research and development (R&D) to focus on technologies in support of operational agility through multi-domain command and control (MDC2) capabilities.</p> <p>This program has been coordinated through the Department of Defense Science and Technology Executive Committee process to harmonize efforts and eliminate duplication.</p> <p>In FY 2020, Project 635319, Anticipatory OPS Intent and Response efforts will be transferred to Project 635321, C4I Battlespace Dev and Demo, in order to realign planning and decision support advanced technology development.</p> <p>In FY 2020, Project 635320, Assured Worldwide Connectivity efforts will be transferred to Project 635321, C4I Battlespace Dev and Demo, in order to realign intelligent networking transport and management advanced technology development.</p> <p>In FY 2020, Project 635322, Knowledge Management and Computing efforts will be transferred to Project 635321, C4/Battlespace Dev and Demo, in order to realign information management advanced technology development.</p> <p>In FY 2020, Project 635321 C4I Battlespace Dev and Demo changed from Global Battlespace Awareness.</p> <p>This program element may include necessary civilian pay expenses required to manage, execute, and deliver science & technology capabilities. The use of program funds in this PE would be in addition to the civilian pay expenses budgeted in program elements 0601102F, 0602102F, 0602201F, 0602202F, 0602203F, 0602204F, 0602602F, 0602605F, 0602788F, 1206601F, and 0602298F.</p> <p>As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.</p> <p>This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.</p>		

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	49.011	51.064	56.961	0.000	56.961
Current President's Budget	45.481	60.017	56.414	0.000	56.414
Total Adjustments	-3.530	8.953	-0.547	0.000	-0.547
• Congressional General Reductions	-0.029	-0.047			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	9.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.580	0.000			
• Other Adjustments	-1.921	0.000	-0.547	0.000	-0.547

Congressional Add Details (\$ in Millions, and Includes General Reductions)

Project: 635320: *Assured Worldwide Connectivity*

Congressional Add: *Program Increase - Assured Worldwide Connectivity*

Congressional Add Subtotals for Project: 635320

Congressional Add Totals for all Projects

	FY 2018	FY 2019
	0.000	9.000
	0.000	9.000
	0.000	9.000

Change Summary Explanation

Decrease in FY 2018 in Other Adjustments is due to realignment of funds to PE 0602212F to support Research and Development Projects, 10 U.S.C. Section 2358.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>				Project (Number/Name) 635319 / <i>Anticipatory OPS Intent and Response</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635319: <i>Anticipatory OPS Intent and Response</i>	-	5.709	6.099	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11.808

A. Mission Description and Budget Item Justification

In order to achieve information dominance, the Air Force must be able to monitor, assess, plan, and execute missions rapidly across the full spectrum of operations (air, space, and cyberspace) at all levels of war (strategic, operational, and tactical) and during all phases of conflict (pre-conflict, conflict through stability operations). This project develops and integrates decision support technologies that will enhance the commander's ability to anticipate and dominate the future battlespace by more effectively forecasting the evolution of the battlespace and by more rapidly generating options to "virtually checkmate" the adversary. It develops the decision aid technologies and processes to plan the use of various assets and assess their effects in the battlespace. It provides a tailorable information environment to effectively portray complex data sets accurately in real-time.

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. In order to enable multi-domain operations, this project will begin to shape future research and development to focus on technologies in support of multi-domain command and control.

In FY 2020, Project 635319, Anticipatory OPS Intent and Response efforts will be transferred to Project 635321, C4I Battlespace Dev and Demo in order to realign technology areas that better support both the Air Force Future Operating Concept and National Defense Strategy.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Adaptive Planning and Decision Tools	3.825	1.739	0.000
Description: Develop and demonstrate the integration of planning tools and information-based intelligent agents for adaptive replanning and decision support tools.			
FY 2019 Plans: Continue to execute experiments, based on operational scenarios, which incorporate process management execution into the extensible Space command and control framework, and which integrate disparate data and applications, providing a pedigree for proposed tasking options to decision makers.			
FY 2020 Plans: Starting in FY 2020, this work is performed under the Multi-Domain Command and Control effort within Project 635321, C4I Battlespace Dev and Demo.			
FY 2019 to FY 2020 Increase/Decrease Statement:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635319 / <i>Anticipatory OPS Intent and Response</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
FY 2020 decreased compared to FY 2019 by \$1.739 million. Funding decreased due to realignment of adaptive planning and decision support tool research under Project 635321, C4I Battlespace Dev and Demo.				
Title: Next Generation Planning and Assessment Tools		1.884	4.360	0.000
Description: Develop and demonstrate an effects-based approach for the next generation of planning and assessment techniques that enable decision makers to determine operational effects.				
FY 2019 Plans: Continue to develop software capabilities that employ cyber, directed energy, and electronic warfare weaponry. Provide on-the-fly valuable quantitative evaluations of cyber assets to cyber operators, enabling them to present viable cyber options to commanders in multi-domain settings. Identify and implement state of the art learning models. Develop data-efficient learning. Integrate within the StreamlinedML framework. Develop end-to-end baseline learning capability. Develop model recommendation & user workflow capabilities.				
FY 2020 Plans: Starting in FY 2020, this work is performed under both Multi-Domain Command and Control, and Artificial Intelligence/Autonomy/ Machine Learning efforts within Project 635321, C4I Battlespace Dev and Demo.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$4.360 million. Funding decreased due to realignment of planning and assessment tool development under Project 635321, C4I Battlespace Dev and Demo.				
Accomplishments/Planned Programs Subtotals		5.709	6.099	0.000
C. Other Program Funding Summary (\$ in Millions) N/A				
Remarks				
D. Acquisition Strategy N/A				
E. Performance Metrics Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>				Project (Number/Name) 635320 / <i>Assured Worldwide Connectivity</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635320: <i>Assured Worldwide Connectivity</i>	-	12.831	21.658	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	34.489

A. Mission Description and Budget Item Justification

The Air Force requires advanced, net-enabled architectures and communications technologies in support of global kinetic and non-kinetic military operations, including a secure information grid for worldwide information delivery and exchange of near-real-time information including voice, data, video, and imagery. This secure environment will be rapidly deployable, mobile, interoperable, and seamless between the Air Operations Center and aircraft, either en route or in theater. This project provides secure information transmission capabilities for a persistent, global, survivable communications backbone network accessible for warfighters operating in all domains. It provides self-healing, self-configuration, anti-jam communication networking capabilities, and provides enterprise networking capabilities for agile, policy-based network management. In addition, this project develops and demonstrates flight ready systems consisting of high capacity radio frequency (RF) and optical components and architectures for next generation communications.

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. In order to enable multi-domain operations, the Air Force requires world-wide connectivity that is resilient and self-healing in the face of enemy attacks on communication and information assurance, able to withstand breaks in connectivity while still allowing users to collaborate with other connected operators to maintain localized situational awareness. The network balances the respective strengths of both forward-deployed forces and rear-based nodes.

In FY 2020, Project 635320, Assured Worldwide Connectivity efforts will be transferred to Project 635321, C4I Battlespace Dev and Demo in order to realign technology areas that better support both the Air Force Future Operating Concept and National Defense Strategy.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Connectivity Technologies	12.831	12.658	0.000
Description: Develop and demonstrate intelligent networking transport and management technology to provide assured, seamless, battlespace connectivity to the Air Force tailored to anti-access/area denial environments and contested operations.			
FY 2019 Plans:			
Continue development and demonstration for rapid waveform development of multi-mission radio frequency capability. Continue Wideband high frequency waveform development and testing. Investigate ionospheric research, propagation modeling and simulation. Perform beacon data collection on both the V and W frequency bands along with waveform development and simulation. Perform airborne testing of very low frequency software defined radio. Develop test platform for Common Very Low Frequency Receiver Increment Two. Demonstrate directional networking prototype. Demonstrate the Variable Rate - multiple-input			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635320 / <i>Assured Worldwide Connectivity</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
and multiple-output clustered delay line technology and a targeting and force protection operational demonstration of integrated and field tested tactical-to-enterprise information management services.			
<i>FY 2020 Plans:</i> Starting in FY 2020, this work is performed under both Assured Communications & Networks and Nuclear C3 Modernization efforts within Project 635321, C4I Battlespace Dev and Demo.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 decreased compared to FY 2019 by \$12.658 million. Funding decreased due to realignment of intelligent networking transport and management technology development under Project 635321, C4I Battlespace Dev and Demo.			
Accomplishments/Planned Programs Subtotals	12.831	12.658	0.000

	FY 2018	FY 2019
<i>Congressional Add:</i> Program Increase - Assured Worldwide Connectivity	0.000	9.000
<i>FY 2018 Accomplishments:</i> Not Applicable		
<i>FY 2019 Plans:</i> Conduct Congressionally directed efforts.		
Congressional Adds Subtotals	0.000	9.000

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>				Project (Number/Name) 635321 / <i>C4I Battlespace Dev and Demo</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635321: <i>C4I Battlespace Dev and Demo</i>	-	5.429	11.242	36.303	0.000	36.303	35.564	37.095	38.153	39.173	Continuing	Continuing

A. Mission Description and Budget Item Justification

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. In order to enable multi-domain operations, this project will begin to shape future research and development to focus on technologies in support of multi-domain command and control.

In order to achieve operational agility, the Air Force must be able (a) to monitor, assess, plan, and execute missions rapidly across the full spectrum of operations at all levels of war and during all phases of conflict; (b) to field advanced, secure, net-enabled architectures and communications/network technologies in support of persistent, global, and survivable kinetic and non-kinetic military operations; (c) to process and exploit data and information from a variety of sources and domains to create a common operating picture of the battlespace; and (d) to provide the decision maker and staff with seamless access to tailored information within a mobile, dynamic, and scalable, globally distributed Air Operations Center, as well as among other producers, consumers, and managers of information relevant to other particular Communities of Interest (COI).

In FY 2020, Project 635319, Anticipatory OPS Intent and Response efforts will be transferred to Project 635321, C4I Battlespace Dev and Demo in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

In FY 2020, Project 635320, Assured Worldwide Connectivity efforts will be transferred to Project 635321, C4I Battlespace Dev and Demo in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

In FY 2020, Project 635322, Knowledge Management and Computing efforts will be transferred to Project 635321, C4I Battlespace Dev and Demo in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

In FY 2020, Project 635321 renamed from Global Battlespace Awareness to C4I Battlespace Dev and Demo.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Advanced Signal and Data Exploitation Technologies	0.517	5.168	0.000
Description: Demonstrate advanced signal and data exploitation technologies for detection, tracking, identification, and targeting of time-critical targets, and information extraction.			
FY 2019 Plans:			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635321 / <i>C4I Battlespace Dev and Demo</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Continue to refine and test technologies for ultra-wideband electronics intelligence signal detection and prosecution. Demonstrate enhanced emitter feature extraction capabilities. Demonstrate automated electronics intelligence analysis tool sets. Complete development, integrate, and demonstrate cyber-physical measurement and signature intelligence capabilities with the Twenty-Fifth Air Force and United States Special Operations Command as transition partners.</p> <p>FY 2020 Plans: Starting in FY 2020, this work is performed under the Data to Decisions effort.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$5.168 million. Funding decreased due to realignment of advanced signal and data exploitation development to the Data to Decisions effort.</p>				
<p>Title: Advanced Data Handling, Visualization and Distributed Data Fusion</p> <p>Description: Develop and demonstrate advanced data handling, event visualization technologies, and distributed data fusion to enable a more effective utilization of data available.</p> <p>FY 2019 Plans: Continue development and demonstration of intelligence analysis capabilities from multiple intelligence sources for both near-real time and post mission. Continue research and development in data analytics and strategic indications and warnings. Demonstrate Seeded Language Modeling demonstration. Advance investigations of real-time deep learning algorithms. Perform service-based capability development. Complete cloud based data and information sharing environment. Continue with Object Based Production optimized processing and automated-association capability.</p> <p>FY 2020 Plans: Starting in FY 2020, this work is performed under the Data to Decisions effort.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$4.363 million. Funding decreased due to realignment of data handling, event visualization, and distributed data fusion development to the Data to Decisions effort.</p>		3.365	4.363	0.000
<p>Title: Autonomous Text Exploitation</p> <p>Description: Develop and demonstrate capabilities for reasoning and learning, text understanding, link and group discovery, and advanced analysis for situational awareness and understanding.</p> <p>FY 2019 Plans:</p>		0.977	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635321 / <i>C4I Battlespace Dev and Demo</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
Starting in FY 2019, this work is performed under the Advanced Signal and Data Exploitation Technologies effort. FY 2020 Plans: Not Applicable FY 2019 to FY 2020 Increase/Decrease Statement: Not Applicable				
Title: Adversary Courses of Action Description: Develop models to provide detailed understanding of the adversary's probable intent and future strategy to identify adversary courses of action, the most likely course of action, and the course of action most dangerous to friendly forces and mission accomplishment. FY 2019 Plans: Continue development and demonstration of full-spectrum targeting and intelligence software tools. Perform operational testing and experimentation on developed semantic capabilities and provide a cross-organization work-flow within intelligence and targeting software. FY 2020 Plans: Starting in FY 2020, this work is performed under the Multi-Domain Command and Control effort. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$1.711 million. Funding decreased due to realignment of all model and course of action development to the Multi-Domain Command and Control effort.		0.570	1.711	0.000
Title: Multi-Domain Command and Control Description: Perform research and development (R&D) that will advance existing, or discover new, command and control capabilities to support multi-domain operations (MDO) for air, space, cyberspace, land, sea, and undersea. FY 2019 Plans: For FY 2019 and prior years, this work is performed under both Adaptive Planning and Decision Tools and Next Generation Planning and Assessment Tools efforts within Project 635319, Anticipatory OPS Intent and Response, and, under the Adversary Courses of Action effort within Project 635321, C4I Battlespace Dev and Demo. FY 2020 Plans: Continue to execute experiments, based on operational scenarios, which incorporate process management execution into the extensible Space command and control framework, and which integrate disparate data and applications, providing a pedigree		0.000	0.000	8.418

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635321 / <i>C4I Battlespace Dev and Demo</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>for proposed tasking options to decision makers. Continue to develop software capabilities that employ cyber, directed energy, and electronic warfare weaponry. Provide on-the-fly valuable quantitative evaluations of cyber assets to cyber operators, enabling them to present viable cyber options to commanders in multi-domain settings.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$8.418 million. Funding increased due to realignment of adaptive planning, decision support, effects-based planning and assessment tool development from Project 635319, Anticipatory OPS Intent and Response, and from the Adversary Courses of Action effort within Project 635321, C4I Battlespace Dev and Demo.</p>				
<p>Title: Nuclear C3 Modernization</p> <p>Description: Develop and demonstrate the advancement of existing nuclear capable forces to ensure command, control, and connectivity for the President without constraints.</p> <p>FY 2019 Plans: For FY 2019 and prior years, this is performed under the Connectivity Technologies effort within Project 635320, Assured Worldwide Connectivity.</p> <p>FY 2020 Plans: Continue to perform real-time monitoring of ionospheric conditions over the Continental United States (CONUS). Continue testing of very-low-frequency (VLF) stub antenna for reachback. Continue testing of prototype compact high-frequency (HF) antennas.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$4.804 million. Funding increased due to the realignment of nuclear command, control, and communications development from Project 635320, Assured Worldwide Connectivity.</p>		0.000	0.000	4.804
<p>Title: Artificial Intelligence/Autonomy/Machine Learning</p> <p>Description: Develop and demonstrate to harness the speed and scale of computers and machines to address problems of complexity.</p> <p>FY 2019 Plans: For FY 2019 and prior years, this work is performed under the Next Generation Planning and Assessment Tools effort within Project 635319, Anticipatory OPS Intent and Response.</p> <p>FY 2020 Plans: Continue to identify and implement state of the art learning models. Continue development of data-efficient learning. Continue to integrate within the StreamlinedML framework. Continue development of end-to-end baseline learning capability. Continue</p>		0.000	0.000	5.295

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635321 / <i>C4I Battlespace Dev and Demo</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
development of model recommendation & user workflow capabilities. Continue investigations of real-time deep learning algorithms. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$5.295 million. Funding increased due to realignment of artificial intelligence, autonomy, and machine learning development from Project 635319, Anticipatory OPS Intent and Response.				
Title: Data to Decisions Description: Develop and demonstrate the collection, management, analysis, and exploitation of complex data for availability to Air Force and other stakeholders. FY 2019 Plans: For FY 2019 and prior years, this work is performed under both the Advanced Signal and Data Exploitation Technologies and the Advanced Data Handling, Visualization and Distributed Data Fusion efforts. FY 2020 Plans: Continue to refine and test technologies for ultra-wideband electronics intelligence signal detection and prosecution. Continue development and demonstration of intelligence analysis capabilities from multiple intelligence sources for both near-real time and post mission. Continue research and development in data analytics and strategic indications and warnings. Perform service-based capability development. Continue with Object Based Production optimized processing and automated-association capability. FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$7.254 million. Funding increased due to realignment of open source and intelligence complex data set collection, management, analysis, and exploitation tool development within both the Advanced Signal and Data Exploitation Technologies and the Advanced Data Handling, Visualization and Distributed Data Fusion efforts.		0.000	0.000	7.254
Title: Assured Communications & Networks Description: Develop and demonstrate secure and reliable communications to ensure the delivery of timely, reliable, and actionable information to warfighters and systems. FY 2019 Plans: For FY 2019 and prior years, this effort performs the work under the Connectivity Technologies effort within Project 635320, Assured Worldwide Connectivity. FY 2020 Plans: Continue development and demonstration for rapid waveform development of multi-mission radio frequency capability. Continue Wideband high frequency waveform development and testing. Investigate ionospheric research, propagation modeling and		0.000	0.000	10.532

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635321 / <i>C4I Battlespace Dev and Demo</i>
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B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
simulation. Continue beacon data collection on both the V and W frequency bands along with waveform development and simulation. Continue airborne testing of very low frequency software defined radio. Continue development of test platform for Common Very Low Frequency Receiver Increment Two.			
<i>FY 2019 to FY 2020 Increase/Decrease Statement:</i> FY 2020 increased compared to FY 2019 by \$10.532 million. Funding increased due to realignment of all secure and reliable communications development from Project 635320, Assured Worldwide Connectivity.			
Accomplishments/Planned Programs Subtotals	5.429	11.242	36.303

C. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635322 / <i>Knowledge Management and Computing</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635322: <i>Knowledge Management and Computing</i>	-	3.299	3.782	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.081

A. Mission Description and Budget Item Justification

The Air Force requires technologies that will provide the decision maker and staff with seamless access to tailored information within a mobile, dynamic, and scalable, globally distributed Air Operations Center, as well as among other producers, consumers, and managers of information relevant to other particular Communities of Interest (COI). This project demonstrates the enterprise management capabilities needed for the rapid distribution of actionable information, as well as the needed advances in high performance computing to ensure this complex capability. This project develops an agile information environment that focuses on quality of service, transformation and brokering, a federated information environment focusing the relationship among the members of the environment, a secure cross-domain information sharing capability that focuses on the security layer and inter-COI information exchange in different security domains, and a collaboration environment focusing on the information workflow layer of the enterprise.

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. In order to enable multi-domain operations, this project will begin to shape future research and development to focus on technologies in support of multi-domain command and control.

In FY 2020, Project 635322, Knowledge Management and Computing efforts will be transferred to Project 635321, C4I Battlespace Dev and Demo in order to realign technology areas that better support the National Defense Strategy and Air Force Future Operating Concept.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Advanced Information Management	3.299	3.782	0.000
Description: Demonstrate how a publish, subscribe, and query information management paradigm can enable vertical and horizontal integration of Air Force information systems.			
FY 2019 Plans:			
Continue plans to develop, demonstrate and transition information management capabilities that securely bridge the gaps between enterprise and tactical domains for increased shared situational awareness across the theater of war for targeting and force protection operations. Continue with capability enhancements and technology hardening based on operational user assessments and collaboration. Execute a Technology Readiness Level 6 targeting and force protection operational demonstration of integrated and field tested tactical-to-enterprise information management services. Improve and update runway survey toolkit plug-in to aid aircraft runway surveys in austere locations. Spearhead geo-location capabilities in Global Positioning			

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635322 / <i>Knowledge Management and Computing</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
System denied environments using elevation, formations, and constellations. Ensure transition and hand-off special tactics plug-ins with Air Force Life Cycle Management Center support to the Battlefield Airman System Program Office.				
FY 2020 Plans: Starting in FY 2020, this work is performed under the Multi-Domain Command & Control effort within Project 635321, C4I Battlespace Dev and Demo.				
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$3.782 million. Funding decreased due to realignment of all information management technology development under Project 635321, C4I Battlespace Dev and Demo.				
Accomplishments/Planned Programs Subtotals		3.299	3.782	0.000
C. Other Program Funding Summary (\$ in Millions) N/A				
Remarks				
D. Acquisition Strategy N/A				
E. Performance Metrics Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.				

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force										Date: February 2019		
Appropriation/Budget Activity 3600 / 3					R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>				Project (Number/Name) 635329 / <i>Cyber Battlespace Dev & Demo</i>			
COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
635329: <i>Cyber Battlespace Dev & Demo</i>	-	18.213	17.236	20.111	0.000	20.111	21.182	23.474	24.146	24.795	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Air Force requires the ability to deliver sovereign options in cyberspace through the development and integration of cyber-attack, cyber defense, and cyber support technologies for a strategic capability of cyber dominance. This project develops the ability to deliver cyber-attack capabilities (access, stealth, persistence, intelligence, and weapons delivery), cyber defense capabilities (attack detection, attack attribution, and response automation) and cyber support capabilities (situation awareness and war gaming). This project will also develop 1) a science and engineering capability demonstrating new models of computation, 2) novel approaches for high performance, interactive, net-centric, distributed and embedded computing systems, and 3) the technological tools enabling affordable, large-scale, and complex software-intensive systems.

The National Defense Strategy and Air Force Future Operating Concept established science and technology challenges to enable operational agility (the ability to rapidly generate and shift among multiple solutions for a given challenge) as a way to adapt swiftly to any situation or enemy action. In order to enable multi-domain operations, this project will begin to shape future research and development to focus on cyber technologies in support of multi-domain command and control.

B. Accomplishments/Planned Programs (\$ in Millions)

	FY 2018	FY 2019	FY 2020
Title: Cyber Offense	3.244	3.881	0.000
Description: Develop and demonstrate offensive cyber operations capabilities in a series of experimental technology demonstrations.			
FY 2019 Plans: Continue to develop systems to identify items of interest associated with the Internet of Things. Facilitate the development of a counter small unmanned aerial system open architecture specification to enable interoperability between disparate protection systems. Demonstrate ground-based and airborne delivery of mitigation (disrupt, deny, degrade, destroy, or deceive) effects, both cyber and physical/kinetic. Integrate and transition multiple Air Force Research Laboratory and Air Force Lifecycle Management Center counter small unmanned aerial system capabilities.			
FY 2020 Plans: Starting in FY 2020, this work is performed under the Cyber Power Projection effort.			
FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$3.881 million. Funding decreased due to realignment of offensive cyber development to Cyber Power Projection effort.			
Title: Effects-based Cyber Defense	4.084	0.000	0.000

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635329 / <i>Cyber Battlespace Dev & Demo</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Description: Integrate technology to demonstrate an effects-based strategic approach to cyber defense that focuses on avoiding, deterring, and minimizing the threat, and rendering the adversary ineffective.</p> <p>FY 2019 Plans: This effort was completed in FY 2018.</p> <p>FY 2020 Plans: Not Applicable</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: Not Applicable</p>				
<p>Title: Resiliency</p> <p>Description: Integrate and demonstrate a resilient and self-generating information enterprise that dynamically recognizes, characterizes, and understands novel cyber attacks, and then reconfigures and self-optimizes itself to resist new attacks.</p> <p>FY 2019 Plans: Develop and evolve software capabilities and Concept of Operations for active guidance and automated processes addressing cyber resiliency and survivability using a relevant system laboratory. Continue capability migration to form factors which more readily align with operational systems. Demonstrate automated cyber survivability using integrated cyber technologies within the operational system laboratory in the context of risk management framework requirements.</p> <p>FY 2020 Plans: Continue to develop and evolve of software capabilities and Concept of Operations for active guidance and automated processes addressing cyber resiliency and survivability. Continue to advance capability migration to form factors which more readily align with operational systems. Continue to demonstrate automated cyber survivability using integrated cyber technologies within the operational system laboratory in the context of risk management framework requirements.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 decreased compared to FY 2019 by \$0.125 million. Justification for this decrease is described in the plans above.</p>		6.997	7.464	7.339
<p>Title: Game Changing Computing Power</p> <p>Description: Develop and demonstrate computer architectures with greater capacity and sophistication to enable game-changing computing power to the warfighter anywhere, anytime.</p> <p>FY 2019 Plans:</p>		2.663	4.779	4.962

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019		
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635329 / <i>Cyber Battlespace Dev & Demo</i>		
B. Accomplishments/Planned Programs (\$ in Millions)		FY 2018	FY 2019	FY 2020
<p>Develop inherently trusted and resilient embedded computing. Improve software specifications using evolutionary approaches and make them inherently tolerant to the unexpected or unforeseen. As part of a trusted and resilient architecture, test and document the secure processor (T-CORE) cyber defenses and other features. Provide support to transition partners and application programmers or the T-CORE specification. Release T-CORE version 2. Continue with Robust Machine Learning upgrades and development. Demonstrate a trusted and resilient embedded system (e.g. autonomous vehicle) that is capable of identifying, localizing and automatically repairing previously unknown or unintended vulnerabilities in the software that is used to support the mission and fight through zero day attacks that exploit these vulnerabilities to cause harm and/or failure to the mission.</p> <p>FY 2020 Plans: Continue to sustain development of inherently trusted and resilient embedded computing. Continue to improve software specifications using evolutionary approaches and make them inherently tolerant to the unexpected or unforeseen. Extend Robust Machine Learning upgrades and development. Continue to demonstrate a trusted and resilient embedded system (e.g. autonomous vehicle) that is capable of identifying, localizing and automatically repairing previously unknown or unintended vulnerabilities in the software</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.183 million. Justification for this increase is described in the plans above.</p>				
<p>Title: Autonomous, Multi-level Access and Transfer</p> <p>Description: Develop autonomous, secure information access and sharing capabilities required by the Air Force net-centric information enterprise.</p> <p>FY 2019 Plans: Continue to develop and integrate a polyglot file identification filter to mitigate data exfiltration risk. Continue to develop a modularized filter store to maximize filter re-usability and increase the agility of cross-domain solutions to support new file types. Demonstrate a Commercial Solution for Classified compliant secure mobile solution that can enforce security policies beyond commercial solutions to satisfy unique Air Force requirements.</p> <p>FY 2020 Plans: Extend development and integration of polyglot file identification filter to mitigate data exfiltration risk. Sustain development of a modularized filter store to maximize filter re-usability and increase the agility of cross-domain solutions to support new file types.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$0.310 million. Justification for this increase is described in the plans above.</p>		1.225	1.112	1.422
<p>Title: Cyber Power Projection</p>		0.000	0.000	6.388

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Exhibit R-2A, RDT&E Project Justification: PB 2020 Air Force		Date: February 2019
Appropriation/Budget Activity 3600 / 3	R-1 Program Element (Number/Name) PE 0603788F / <i>Battlespace Knowledge Development and Demonstration</i>	Project (Number/Name) 635329 / <i>Cyber Battlespace Dev & Demo</i>

B. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
<p>Description: Develop and demonstrate offensive cyber capabilities in contested environments through a series of experiments and exercises.</p> <p>FY 2019 Plans: For FY 2019 and prior years, this work is performed under the Cyber Offense effort.</p> <p>FY 2020 Plans: Extend development of systems to identify items of interest associated with the Internet of Things. Advance the development of a counter small unmanned aerial system open architecture specification to enable interoperability between disparate protection systems. Continue to integrate and transition multiple Air Force Research Laboratory and Air Force Lifecycle Management Center counter small unmanned aerial system capabilities. Provide capability to enable the warfighter access into congested environments as directed by warfighter requirements.</p> <p>FY 2019 to FY 2020 Increase/Decrease Statement: FY 2020 increased compared to FY 2019 by \$6.388 million. Funding increased due to realignment of offensive cyber operations development from Cyber Offense effort.</p>			
Accomplishments/Planned Programs Subtotals	18.213	17.236	20.111

C. Other Program Funding Summary (\$ in Millions)
N/A

Remarks

D. Acquisition Strategy
N/A

E. Performance Metrics
Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0303467F / <i>SENSR Spectrum Pipeline SRF</i>
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COST (\$ in Millions)	Prior Years	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total	FY 2021	FY 2022	FY 2023	FY 2024	Cost To Complete	Total Cost
Total Program Element	-	2.188	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Continuing	Continuing
632610: <i>Activities</i>	-	2.188	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Continuing	Continuing

A. Mission Description and Budget Item Justification

The Commercial Spectrum Enhancement Act (CSEA) of 2004 created the Spectrum Relocation Fund (CSEA, Title II of P.L. 108-494) to provide a centralized and streamlined funding mechanism through which Federal agencies can recover the costs associated with relocating their radio communications systems from certain spectrum bands, which were authorized to be auctioned for commercial purposes.

The Department of Defense (DoD) Spectrum Access Research and Development Program (SAR&DP) encompasses spectrum technology development that enables Department of Defense spectrum-dependent systems to satisfy operational readiness and capability needs. Being able to operate in accordance with spectrum allocations resulting after the spectrum auction is necessary, but not sufficient, for pursued technology solutions. The Department of Defense transition out of or sharing of the auctioned bands can only be successful if the research and development solutions are effective (for example, survivable, electronically protected, et cetera) while operating in both the United States and congested/contested spectrum environments wherever forces will be deployed.

This program represents the Air Force investment within the SAR&DP. Budget for the Air Force portion of the DoD SAR&DP is created from the auction of Advanced Wireless Service licenses in execution year.

Funding supports Spectrum relocation and sharing activities.

As directed in the FY 2018 NDAA, Sec 825, amendment to PL 114-92 FY 2016 NDAA, Sec 828 Penalty for Cost Overruns, the FY 2018 Air Force penalty total is \$14.373M. The calculated percentage reduction to each research, development, test and evaluation and procurement account will be allocated proportionally from all programs, projects, or activities under such account.

This program is in Budget Activity 3, Advanced Technology Development because this budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force **Date:** February 2019

Appropriation/Budget Activity 3600: Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)	R-1 Program Element (Number/Name) PE 0303467F I SENSr Spectrum Pipeline SRF
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B. Program Change Summary (\$ in Millions)	FY 2018	FY 2019	FY 2020 Base	FY 2020 OCO	FY 2020 Total
Previous President's Budget	0.000	0.000	0.000	0.000	0.000
Current President's Budget	2.188	0.000	0.000	0.000	0.000
Total Adjustments	2.188	0.000	0.000	0.000	0.000
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• Other Adjustments	2.188	0.000	0.000	0.000	0.000

Change Summary Explanation

Other Adjustment of \$2.188 million in FY 2018 due to Air Force portion of the Department of Defense Spectrum Access Research and Development Program created from the auction of Advanced Wireless Service licenses. Receive funds during execution year through a transfer from OMB.

C. Accomplishments/Planned Programs (\$ in Millions)	FY 2018	FY 2019	FY 2020
Title: Air Force Spectrum Access Research & Development Program (SAR&DP)	2.188	0.000	0.000
Description: The SAR&DP encompasses spectrum technology development that enables Department of Defense spectrum-dependent systems to satisfy operational readiness and capability needs. Being able to operate in accordance with spectrum allocations resulting after the spectrum auction is necessary, but not sufficient, for pursued technology solutions. The Department of Defense transition out of or sharing of the auctioned bands can only be successful if the research and development solutions are effective (for example, survivable, electronically protected, et cetera) while operating in both the United States and congested/contested spectrum environments wherever forces will be deployed.			
FY 2019 Plans: No change from FY 2019 to FY 2020. Budget for the Air Force portion of the Department of Defense Spectrum Access Research and Development Program is created from the auction of Advanced Wireless Service licenses.			
FY 2020 Plans: N/A			
FY 2019 to FY 2020 Increase/Decrease Statement: N/A			
Accomplishments/Planned Programs Subtotals	2.188	0.000	0.000

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Exhibit R-2, RDT&E Budget Item Justification: PB 2020 Air Force	Date: February 2019
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Appropriation/Budget Activity 3600: <i>Research, Development, Test & Evaluation, Air Force I BA 3: Advanced Technology Development (ATD)</i>	R-1 Program Element (Number/Name) PE 0303467F / <i>SENSR Spectrum Pipeline SRF</i>
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D. Other Program Funding Summary (\$ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Please refer to the Performance Base Budget Overview Book for information on how Air Force resources are applied and how those resources are contributing to Air Force performance goals and most importantly, how they contribute to our mission.

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