Department of Defense
Fiscal Year (FY) 2019 Budget Estimates

February 2018

Defense Advanced Research Projects Agency

Defense-Wide Justification Book Volume 1 of 5

Research, Development, Test & Evaluation, Defense-Wide

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Department of Defense
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Appropriation	FY 2017 (Base + OCO)	FY 2018 PB Request with CR Adj Base	FY 2018 Total PB Requests* with CR Adj Base	FY 2018 PB Request with CR Adj OCO	FY 2018 Total PB Requests+ with CR Adj OCO
Research, Development, Test & Eval, DW	2,887,661	3,170,390	3,170,390		
Total Research, Development, Test & Evaluation	2,887,661	3,170,390	3,170,390		

Department of Defense
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Appropriation	FY 2018 Emergency Requests** Emergency	FY 2018 Less Enacted Div B P.L.115-96*** MDDE + Ship Repairs	FY 2018 Remaining Req Emergency	FY 2018 Total PB Requests* with CR Adj Base + OCO + Emergency**	FY 2018 Less Enacted DIV B P.L.115-96*** MDDE + Ship Repairs	FY 2018 Remaining Req with CR Adj Base + OCO + Emergency
Research, Development, Test & Eval, DW				3,170,390		3,170,390
Total Research, Development, Test & Evaluation				3,170,390		3,170,390

Department of Defense
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Appropriation	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Research, Development, Test & Eval, DW	3,438,766		3,438,766
Total Research, Development, Test & Evaluation	3,438,766		3,438,766

Department of Defense
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Summary Recap of Budget Activities	FY 2017 (Base + OCO)	FY 2018 PB Request with CR Adj Base	FY 2018 Total PB Requests* with CR Adj Base	FY 2018 PB Request with CR Adj OCO	FY 2018 Total PB Requests+ with CR Adj OCO
Basic Research	399,111	475,473	475,473		
Applied Research	1,143,023	1,378,821	1,378,821		
Advanced Technology Development	1,177,564	1,238,310	1,238,310		
Management Support	167,963	77,786	77,786		
Total Research, Development, Test & Evaluation	2,887,661	3,170,390	3,170,390		
Summary Recap of FYDP Programs					
Research and Development	2,887,661	3,170,390	3,170,390		
Total Research, Development, Test & Evaluation	2,887,661	3,170,390	3,170,390		

R-119PB: FY 2019 President's Budget (Published Version), as of January 26, 2018 at 12:42:28

Department of Defense
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Summary Recap of Budget Activities	FY 2018 Emergency Requests** Emergency	FY 2018 Less Enacted Div B P.L.115-96*** MDDE + Ship Repairs	FY 2018 Remaining Req Emergency	FY 2018 Total PB Requests* with CR Adj Base + OCO + Emergency**	FY 2018 Less Enacted DIV B P.L.115-96*** MDDE + Ship Repairs	FY 2018 Remaining Req with CR Adj Base + OCO + Emergency
Basic Research				475,473		475,473
Applied Research				1,378,821		1,378,821
Advanced Technology Development				1,238,310		1,238,310
Management Support				77,786		77,786
Total Research, Development, Test & Evaluation				3,170,390		3,170,390
Summary Recap of FYDP Programs						
Research and Development				3,170,390		3,170,390
Total Research, Development, Test & Evaluation				3,170,390		3,170,390

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Department of Defense
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Summary Recap of Budget Activities	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Basic Research	469,955		469,955
Applied Research	1,431,468		1,431,468
Advanced Technology Development	1,458,054		1,458,054
Management Support	79,289		79,289
Total Research, Development, Test & Evaluation	3,438,766		3,438,766

Summary Recap of FYDP Programs			
Research and Development	3,438,766		3,438,766
Total Research, Development, Test & Evaluation	3,438,766		3,438,766

Defense-Wide
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Applied Research				1,378,821		1,378,821
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Management Support				77,786		77,786
Total Research, Development, Test & Evaluation				3,170,390		3,170,390

Summary Recap of FYDP Programs						
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Total Research, Development, Test & Evaluation	2,887,661	3,170,390	3,170,390		

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Defense Advanced Research Projects Agency				3,170,390		3,170,390
Total Research, Development, Test & Evaluation				3,170,390		3,170,390

Defense-Wide
FY 2019 President's Budget
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26 Jan 2018

Appropriation	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Defense Advanced Research Projects Agency	3,438,766		3,438,766
Total Research, Development, Test & Evaluation	3,438,766		3,438,766

Defense-Wide
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Appropriation: 0400D Research, Development, Test & Eval, DW

Line No	Program Element Number	Item	Act	FY 2017 (Base + OCO)	FY 2018 PB Request with CR Adj Base	FY 2018 Total PB Requests* with CR Adj Base	FY 2018 PB Request with CR Adj OCO	FY 2018 Total PB Requests+ with CR Adj OCO	Sec
2	0601101E	Defense Research Sciences	01	356,861	432,347	432,347			U
4	0601117E	Basic Operational Medical Research Science	01	42,250	43,126	43,126			U
	Basic Research			399,111	475,473	475,473			
9	0602115E	Biomedical Technology	02	95,801	109,360	109,360			U
13	0602303E	Information & Communications Technology	02	341,942	392,784	392,784			U
14	0602383E	Biological Warfare Defense	02	20,453	13,014	13,014			U
17	0602702E	Tactical Technology	02	285,348	343,776	343,776			U
18	0602715E	Materials and Biological Technology	02	208,855	224,440	224,440			U
19	0602716E	Electronics Technology	02	190,624	295,447	295,447			U
	Applied Research			1,143,023	1,378,821	1,378,821			
34	0603286E	Advanced Aerospace Systems	03	180,780	155,406	155,406			U
35	0603287E	Space Programs and Technology	03	162,643	247,435	247,435			U
55	0603739E	Advanced Electronics Technologies	03	52,990	79,173	79,173			U
56	0603760E	Command, Control and Communications Systems	03	123,934	106,787	106,787			U
57	0603766E	Network-Centric Warfare Technology	03	417,826	439,386	439,386			U
58	0603767E	Sensor Technology	03	239,391	210,123	210,123			U
	Advanced Technology Development			1,177,564	1,238,310	1,238,310			
141	0605001E	Mission Support	06	69,244	63,769	63,769			U

Defense-Wide
FY 2019 President's Budget
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(Dollars in Thousands)

26 Jan 2018

Appropriation: 0400D Research, Development, Test & Eval, DW

Line No	Program Element Number	Item	Act	FY 2018 Emergency Requests** Emergency	FY 2018 Less Enacted Div B P.L.115-96*** MDDE + Ship Repairs	FY 2018 Remaining Req Emergency	FY 2018 Total PB Requests* with CR Adj Base + OCO + Emergency**	FY 2018 Less Enacted DIV B P.L.115-96*** MDDE + Ship Repairs	FY 2018 Remaining Req with CR Adj Base + OCO + Emergency	Sec
2	0601101E	Defense Research Sciences	01				432,347		432,347	U
4	0601117E	Basic Operational Medical Research Science	01				43,126		43,126	U
		Basic Research					475,473		475,473	
9	0602115E	Biomedical Technology	02				109,360		109,360	U
13	0602303E	Information & Communications Technology	02				392,784		392,784	U
14	0602383E	Biological Warfare Defense	02				13,014		13,014	U
17	0602702E	Tactical Technology	02				343,776		343,776	U
18	0602715E	Materials and Biological Technology	02				224,440		224,440	U
19	0602716E	Electronics Technology	02				295,447		295,447	U
		Applied Research					1,378,821		1,378,821	
34	0603286E	Advanced Aerospace Systems	03				155,406		155,406	U
35	0603287E	Space Programs and Technology	03				247,435		247,435	U
55	0603739E	Advanced Electronics Technologies	03				79,173		79,173	U
56	0603760E	Command, Control and Communications Systems	03				106,787		106,787	U
57	0603766E	Network-Centric Warfare Technology	03				439,386		439,386	U
58	0603767E	Sensor Technology	03				210,123		210,123	U
		Advanced Technology Development					1,238,310		1,238,310	
141	0605001E	Mission Support	06				63,769		63,769	U

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Defense-Wide
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Appropriation: 0400D Research, Development, Test & Eval, DW

Line No	Program Element Number	Item	Act	FY 2019 Base	FY 2019 OCO	FY 2019 Total	Sec
2	0601101E	Defense Research Sciences	01	422,130		422,130	U
4	0601117E	Basic Operational Medical Research Science	01	47,825		47,825	U
	Basic Research			469,955		469,955	
9	0602115E	Biomedical Technology	02	101,300		101,300	U
13	0602303E	Information & Communications Technology	02	395,317		395,317	U
14	0602383E	Biological Warfare Defense	02	38,640		38,640	U
17	0602702E	Tactical Technology	02	335,466		335,466	U
18	0602715E	Materials and Biological Technology	02	226,898		226,898	U
19	0602716E	Electronics Technology	02	333,847		333,847	U
	Applied Research			1,431,468		1,431,468	
34	0603286E	Advanced Aerospace Systems	03	277,603		277,603	U
35	0603287E	Space Programs and Technology	03	254,671		254,671	U
55	0603739E	Advanced Electronics Technologies	03	111,099		111,099	U
56	0603760E	Command, Control and Communications Systems	03	185,984		185,984	U
57	0603766E	Network-Centric Warfare Technology	03	438,569		438,569	U
58	0603767E	Sensor Technology	03	190,128		190,128	U
	Advanced Technology Development			1,458,054		1,458,054	
141	0605001E	Mission Support	06	65,646		65,646	U

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Defense-Wide
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Appropriation: 0400D Research, Development, Test & Eval, DW

Line No	Program Element Number	Item	Act	FY 2017 (Base + OCO)	FY 2018 PB Request with CR Adj Base	FY 2018 Total PB Requests* with CR Adj Base	FY 2018 PB Request with CR Adj OCO	FY 2018 Total PB Requests+ with CR Adj OCO	Sec
156	0605502E	Small Business Innovative Research	06	94,860					U
164	0605898E	Management HQ - R&D	06	3,859	14,017	14,017			U
		Management Support		167,963	77,786	77,786			
Total Research, Development, Test & Eval, DW				2,887,661	3,170,390	3,170,390			

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156	0605502E	Small Business Innovative Research	06							U
164	0605898E	Management HQ - R&D	06				14,017		14,017	U
		Management Support					77,786		77,786	
Total Research, Development, Test & Eval, DW							3,170,390		3,170,390	

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Line No	Program Element Number	Item	Act	FY 2019 Base	FY 2019 OCO	FY 2019 Total	Sec
156	0605502E	Small Business Innovative Research	06				U
164	0605898E	Management HQ - R&D	06	13,643		13,643	U
		Management Support		79,289		79,289	
Total Research, Development, Test & Eval, DW				3,438,766		3,438,766	

Defense Advanced Research Projects Agency
FY 2019 President's Budget
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Basic Research				399,111	475,473	475,473			
9	0602115E	Biomedical Technology	02	95,801	109,360	109,360			U
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Applied Research				1,143,023	1,378,821	1,378,821			
34	0603286E	Advanced Aerospace Systems	03	180,780	155,406	155,406			U
35	0603287E	Space Programs and Technology	03	162,643	247,435	247,435			U
55	0603739E	Advanced Electronics Technologies	03	52,990	79,173	79,173			U
56	0603760E	Command, Control and Communications Systems	03	123,934	106,787	106,787			U
57	0603766E	Network-Centric Warfare Technology	03	417,826	439,386	439,386			U
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35	0603287E	Space Programs and Technology	03				247,435		247,435	U
55	0603739E	Advanced Electronics Technologies	03				79,173		79,173	U
56	0603760E	Command, Control and Communications Systems	03				106,787		106,787	U
57	0603766E	Network-Centric Warfare Technology	03				439,386		439,386	U
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Advanced Technology Development							1,238,310		1,238,310	
141	0605001E	Mission Support	06				63,769		63,769	U

Defense Advanced Research Projects Agency
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57	0603766E	Network-Centric Warfare Technology	03	438,569		438,569	U
58	0603767E	Sensor Technology	03	190,128		190,128	U
Advanced Technology Development				1,458,054		1,458,054	
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164	0605898E	Management HQ - R&D	06	3,859	14,017	14,017			U
	Management Support			167,963	77,786	77,786			
Total Defense Advanced Research Projects Agency				2,887,661	3,170,390	3,170,390			

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156	0605502E	Small Business Innovative Research	06							U
164	0605898E	Management HQ - R&D	06				14,017		14,017	U
		Management Support					77,786		77,786	
Total Defense Advanced Research Projects Agency							3,170,390		3,170,390	

R-119PB: FY 2019 President's Budget (Published Version), as of January 26, 2018 at 12:42:28

Defense Advanced Research Projects Agency
FY 2019 President's Budget
Exhibit R-1 FY 2019 President's Budget
Total Obligational Authority
(Dollars in Thousands)

26 Jan 2018

Appropriation: 0400D Research, Development, Test & Eval, DW

Line No	Program Element Number	Item	Act	FY 2019 Base	FY 2019 OCO	FY 2019 Total	Sec
156	0605502E	Small Business Innovative Research	06				U
164	0605898E	Management HQ - R&D	06	13,643		13,643	U
	Management Support			79,289		79,289	
Total Defense Advanced Research Projects Agency				3,438,766		3,438,766	

R-119PB: FY 2019 President's Budget (Published Version), as of January 26, 2018 at 12:42:28

Program Element Table of Contents (by Budget Activity then Line Item Number)

Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Line #	Budget Activity	Program Element Number	Program Element Title	Page
2	01	0601101E	DEFENSE RESEARCH SCIENCES	Volume 1 - 1
4	01	0601117E	BASIC OPERATIONAL MEDICAL SCIENCE	Volume 1 - 45

Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Line #	Budget Activity	Program Element Number	Program Element Title	Page
9	02	0602115E	BIOMEDICAL TECHNOLOGY	Volume 1 - 51
13	02	0602303E	INFORMATION & COMMUNICATIONS TECHNOLOGY	Volume 1 - 59
14	02	0602383E	BIOLOGICAL WARFARE DEFENSE	Volume 1 - 89
17	02	0602702E	TACTICAL TECHNOLOGY	Volume 1 - 93
18	02	0602715E	MATERIALS AND BIOLOGICAL TECHNOLOGY	Volume 1 - 119
19	02	0602716E	ELECTRONICS TECHNOLOGY	Volume 1 - 137

Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Line #	Budget Activity	Program Element Number	Program Element Title	Page
34	03	0603286E	ADVANCED AEROSPACE SYSTEMS	Volume 1 - 161
35	03	0603287E	SPACE PROGRAMS AND TECHNOLOGY	Volume 1 - 171
55	03	0603739E	ADVANCED ELECTRONICS TECHNOLOGIES	Volume 1 - 181
56	03	0603760E	COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS	Volume 1 - 193
57	03	0603766E	NETWORK-CENTRIC WARFARE TECHNOLOGY	Volume 1 - 205
58	03	0603767E	SENSOR TECHNOLOGY	Volume 1 - 223

Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Line #	Budget Activity	Program Element Number	Program Element Title	Page
141	06	0605001E	MISSION SUPPORT	Volume 1 - 239
156	06	0605502E	SMALL BUSINESS INNOVATION RESEARCH	Volume 1 - 241
164	06	0605898E	MANAGEMENT HQ - R&D	Volume 1 - 243

Program Element Table of Contents (Alphabetically by Program Element Title)

Program Element Title	Program Element Number	Line #	BA	Page
ADVANCED AEROSPACE SYSTEMS	0603286E	34	03	Volume 1 - 161
ADVANCED ELECTRONICS TECHNOLOGIES	0603739E	55	03	Volume 1 - 181
BASIC OPERATIONAL MEDICAL SCIENCE	0601117E	4	01	Volume 1 - 45
BIOLOGICAL WARFARE DEFENSE	0602383E	14	02	Volume 1 - 89
BIOMEDICAL TECHNOLOGY	0602115E	9	02	Volume 1 - 51
COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS	0603760E	56	03	Volume 1 - 193
DEFENSE RESEARCH SCIENCES	0601101E	2	01	Volume 1 - 1
ELECTRONICS TECHNOLOGY	0602716E	19	02	Volume 1 - 137
INFORMATION & COMMUNICATIONS TECHNOLOGY	0602303E	13	02	Volume 1 - 59
MANAGEMENT HQ - R&D	0605898E	164	06	Volume 1 - 243
MATERIALS AND BIOLOGICAL TECHNOLOGY	0602715E	18	02	Volume 1 - 119
MISSION SUPPORT	0605001E	141	06	Volume 1 - 239
NETWORK-CENTRIC WARFARE TECHNOLOGY	0603766E	57	03	Volume 1 - 205
SENSOR TECHNOLOGY	0603767E	58	03	Volume 1 - 223
SMALL BUSINESS INNOVATION RESEARCH	0605502E	156	06	Volume 1 - 241
SPACE PROGRAMS AND TECHNOLOGY	0603287E	35	03	Volume 1 - 171
TACTICAL TECHNOLOGY	0602702E	17	02	Volume 1 - 93

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	356.861	432.347	422.130	-	422.130	413.970	403.528	396.635	384.423	-	-
CCS-02: *MATH AND COMPUTER SCIENCES*	-	145.091	169.069	160.153	-	160.153	181.256	184.896	182.536	181.536	-	-
CYS-01: *CYBER SCIENCES*	-	45.753	41.176	16.251	-	16.251	0.000	0.000	0.000	0.000	-	-
ES-01: *ELECTRONIC SCIENCES*	-	60.591	86.626	49.546	-	49.546	35.783	34.883	34.883	34.883	-	-
ES-02: *BEYOND SCALING SCIENCES*	-	0.000	0.000	55.100	-	55.100	55.880	54.390	53.600	53.290	-	-
MS-01: *MATERIALS SCIENCES*	-	59.083	75.599	85.569	-	85.569	83.837	85.138	85.138	85.138	-	-
TRS-01: *TRANSFORMATIVE SCIENCES*	-	46.343	59.877	55.511	-	55.511	57.214	44.221	40.478	29.576	-	-

A. Mission Description and Budget Item Justification

The Defense Research Sciences Program Element is budgeted in the Basic Research Budget Activity because it provides the technical foundation for long-term National Security enhancement through the discovery of new phenomena and the exploration of the potential of such phenomena for Defense applications. It supports the scientific study and experimentation that is the basis for more advanced knowledge and understanding in information, electronic, mathematical, computer, and materials sciences.

The Math and Computer Sciences project supports scientific study and experimentation on new mathematical and computational algorithms, models, and mechanisms in support of long-term national security requirements. Modern analytic and information technologies enable important new military capabilities and drive the productivity gains essential to U.S. economic competitiveness. Conversely, new classes of threats, in particular threats that operate in or through the cyber domain, put military systems, critical infrastructure, and the civilian economy at risk. This project aims to magnify these opportunities and mitigate these threats by leveraging emerging mathematical and computational capabilities including computational social science, artificial intelligence, machine learning and reasoning, data science, complex systems modeling and simulation, and theory of computation. The basic research conducted under the Math and Computer Sciences project will produce breakthroughs that enable new capabilities for national security and homeland defense.

The Cyber Sciences project supports long term national security requirements through scientific research and experimentation in cyber security. Information technologies enable important new military capabilities and drive the productivity gains essential to U.S. economic competitiveness. Meanwhile, cyber threats grow in sophistication and number, and put sensitive data, classified computer programs, mission-critical information systems, and future economic gains at risk. The basic research conducted under the Cyber Sciences project will produce breakthroughs necessary to enhance the resilience of DoD information systems to current and emerging cyber threats.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*

The Electronic Sciences project is for basic exploration of electronic and optoelectronic devices, circuits, and processing concepts to meet the military's need for near real-time information gathering, transmission, and processing. In seeking to continue the phenomenal progress in microelectronics innovation that has characterized the last few decades, the project should provide DoD with new, improved, or potentially revolutionary device options for accomplishing these critical functions. The resulting technologies should help maintain knowledge of the enemy, communicate decisions based on that knowledge, and substantially improve the cost and performance of military systems. The Beyond Scaling programs in this project will support investigations into materials, devices, and architectures to provide continued improvements in electronics performance with or without the benefit of Moore's Law (silicon scaling). Within the next ten years, traditional scaling will start to encounter the fundamental physical limits of silicon, requiring fresh approaches to new electronic systems.

The Beyond Scaling Sciences project will support investigations into materials, devices, and architectures to provide continued improvements in electronics performance with or without the benefit of Moore's Law (silicon scaling). Within the next ten years, traditional scaling will start to encounter the fundamental physical limits of silicon, requiring fresh approaches to new electronic systems. Over the short term, DoD will therefore need to unleash circuit specialization in order to maximize the benefit of traditional silicon. Over the longer term, DoD and the nation will need to engage the computer, material, and mechanical sciences to explore electronics improvements through vertical circuit integration for improved computation or non-volatile memory devices that combine computation and memory. Other memory devices could also leverage an emerging understanding of the physics of magnetic states, electron spin properties, topological insulators, or phase-changing materials. Beyond Scaling programs will address fundamental exploration into each of these areas. This Project is not a new start. It aggregates and continues Beyond Scaling programs that were initiated in Projects ES-01 and CCS-02 in this same Program Element.

The Materials Sciences project provides the fundamental research that underpins the design, development, assembly, and optimization of advanced materials, devices, and systems for DoD applications in areas such as robust diagnostics and therapeutics, novel energetic materials, and complex hybrid systems.

The Transformative Sciences project supports research and analysis that leverages converging technological forces and transformational trends in computing and the computing-reliant subareas of the social sciences, life sciences, manufacturing, and commerce. The project integrates these diverse disciplines to improve military adaptation to sudden changes in requirements, threats, and emerging/converging trends, especially trends that have the potential to disrupt military operations.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	362.297	432.347	410.178	-	410.178
Current President's Budget	356.861	432.347	422.130	-	422.130
Total Adjustments	-5.436	0.000	11.952	-	11.952
• 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	1.140	0.000			
• SBIR/STTR Transfer	-6.576	0.000			
• TotalOtherAdjustments	-	-	11.952	-	11.952

Change Summary Explanation

FY 2017: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.

FY 2018: N/A

FY 2019: Increase reflects additional funding supporting the Electronics Resurgence Initiative (ERI) in the Beyond Scaling Sciences project.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) CCS-02 / *MATH AND COMPUTER SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
CCS-02: *MATH AND COMPUTER SCIENCES*	-	145.091	169.069	160.153	-	160.153	181.256	184.896	182.536	181.536	-	-

A. Mission Description and Budget Item Justification

The Math and Computer Sciences project supports scientific study and experimentation on new mathematical and computational algorithms, models, and mechanisms in support of long-term national security requirements. Modern analytic and information technologies enable important new military capabilities and drive the productivity gains essential to U.S. economic competitiveness. Conversely, new classes of threats, in particular threats that operate in or through the cyber domain, put military systems, critical infrastructure, and the civilian economy at risk. This project aims to magnify these opportunities and mitigate these threats by leveraging emerging mathematical and computational capabilities including computational social science, artificial intelligence, machine learning and reasoning, data science, complex systems modeling and simulation, and theory of computation. The basic research conducted under the Math and Computer Sciences project will produce breakthroughs that enable new capabilities for national security and homeland defense.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Human Social Systems	7.640	16.400	24.000

Description: The social sciences provide essential theories and models that can enable deeper understanding of human social systems and behaviors relevant to national security such as humanitarian aid, disaster relief, and stability support missions, as well as tactical, operational, strategic, and policy-level decision-making across the DoD. However, current limitations to the speed, scalability and reproducibility of empirical social science research continue to hamper its practical use by the DoD. One focus area of the Human Social Systems thrust is to develop and validate new methods, models and tools to perform rigorous, reproducible experimental research at scales necessary to understand emergent properties of human social systems. Another focus area is to identify methods to better characterize and quantify properties, dynamics and behaviors of different social systems to enable better and more confident forecasting of changes in social systems, particularly when under stress. This research thrust will provide DoD with new, reliable strategies to better understand and respond to social system issues at city scale.

FY 2018 Plans:

- Develop new capabilities for experimentally testing and validating multiple models of human social systems and behaviors.
- Demonstrate the applicability of newly developed representation and modeling tools for understanding potential social behavioral outcomes.
- Test newly developed representation and modeling tools to determine applicability for understanding social behavioral outcomes.
- Begin to leverage inherent bias in artificial intelligence (AI) systems.

FY 2019 Plans:

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Integrate new capabilities for experimentally testing and validating multiple models of human social systems and behavior. - Develop scoring methods to quantify the predictive accuracy of different models across different social experimental designs. - Test the efficiency and value of enhanced reproducibility for accelerating rigorous understanding of human social systems and behaviors. - Develop and deploy increasingly complex social simulations with known causal ground truth as test bed challenges for social science research communities. - Quantify the diagnostic and predictive accuracy, robustness, and efficiency of social science representation and modeling tools by testing them against simulations. - Determine the capabilities and limitations of representation and modeling tools for understanding and predicting cause and effect in complex social systems. - Measure bias in systems trained on distinct training sets. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects expansion into testing and modeling phases of understanding human social systems.			
Title: Synergistic Discovery and Design (SD2)	13.000	21.000	23.000
Description: The Synergistic Discovery and Design (SD2) program is developing data-driven methods to accelerate scientific discovery and robust design in domains that lack complete models. Engineers regularly use high-fidelity simulations to create robust designs in complex domains such as aeronautics and integrated circuits. In contrast, robust design remains elusive in domains such as synthetic biology, neuro-computation, and synthetic chemistry due to the lack of high-fidelity models. The SD2 program is developing tools to enable robust design despite the lack of complete scientific models. This involves collecting raw experimental data into a data and analysis hub, developing computational techniques that extract scientific knowledge directly from experimental data, and creating data sharing tools and metrics that facilitate collaborative design. SD2 application domains include synthetic biology, solar cell chemistry, and protein design. ***FY 2018 Plans:*** - Develop baseline scientific discovery algorithms that detect why experiments fail and enhance reproducibility of sensor and circuit design experiments. - Establish automated design tools for biological circuit and protein design to accelerate design of molecular sensors. - Develop experimental planning tools to optimize cost trade-offs for biological circuit and protein design experiments. - Generate cross laboratory datasets and evaluate the extent to which scientific discovery and design tools accelerate the design of biological circuits and proteins. ***FY 2019 Plans:*** - Extend scientific discovery algorithms to identify root causes for experimental surprises.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Improve accuracy of protein design tools and extend design tool capabilities to enable biological circuit design. - Extend experimental planning tools to facilitate design of experiments that maximize information gained on a per-experiment basis. - Extend baseline protocol capture software to enable assembly of high-quality, integrated experimental data and evaluate generalizability of approach. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development and refinement of techniques and software tools to enable scientific discovery and design in domains that lack robust models.			
Title: Advanced Tools for Modeling and Simulation	12.346	13.466	18.280
Description: The Advanced Tools for Modeling and Simulation thrust will develop foundational mathematical and computational theories, approaches and tools to better represent, quantify and model complex DoD systems from multimodal data analysis through part/system design and fabrication. One focus area of this thrust is developing a unified mathematical framework to enable better visualization and analysis of massive, complex data sets. Rigorous mathematical theories are also being developed to address uncertainty in the modeling and design of complex multi-scale physical and engineering systems, incorporating capabilities to handle noisy data and model uncertainty that are well beyond the scope of current capabilities. Other work in this thrust focuses on developing the mathematical and computational tools required to generate and better manage the enormous complexity of design, ultimately allowing designers to more easily discover non-intuitive (yet realizable) designs that fully leverage new materials and advanced manufacturing approaches now available. Outcomes from this thrust will improve the speed and accuracy of modeling and simulation, as well as enable management of complexity across DoD devices, parts and systems. ***FY 2018 Plans:*** - Explore techniques to extract promising designs from a vast multi-dimensional design space. - Demonstrate novel mathematical and computation tools that integrate geometry with materials, including micro-structure architectures, to accelerate design exploration and optimization subject to a single physics. - Explore alternative representations to describe design problem formulation. - Begin to fabricate and evaluate integrated testbeds with novel hybrid analog and digital computational architectures for simulating complex, non-linear systems. - Develop machine learning and computational techniques based on topological methods and spectral analysis for identifying and tracking non-equilibrium behavior. - Analyze limits for several current machine-learning problems and assess the performance of state-of-the-art approaches with respect to these limits. - Propose new methods or principles to guide development of systems based on machine learning.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Establish new fundamental mathematics and computer science building blocks for conceptual design. ***FY 2019 Plans:*** - Evaluate novel mathematical and computation tools that integrate geometry with materials against DoD relevant challenge design problems. - Demonstrate ability to extract designs from a vast multi-dimensional design space. - Transition viable advanced design algorithms to government stakeholders. - Demonstrate rapidly adaptable conceptual design on a DoD relevant problem. - Explore use of novel conceptual design mathematics and computer science building blocks for evolutionary design. - Transition novel conceptual design software prototypes to government partners for exploration. - Develop general approach to automate creation of adaptable virtual models from heterogeneous data. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects new investments in fundamentals of design effort.			
Title: World Modelers	10.863	16.800	18.600
Description: The World Modelers program is creating explanatory models for natural and human-mediated systems at regional and global scales. The world is highly interdependent, and disruption of natural resources, supply chains, and production systems can have severe consequences. The World Modelers capability is focused on regional and global systems with the goal of generating timely indications and warnings of impending catastrophe. Water and food security are application domains of particular interest, as persistent drought may cause crops to fail, leading to migration and regional conflicts. The World Modelers program is developing techniques for automating the creation, maintenance, and validation of large-scale integrated models using publicly available news and analyst reports as a structuring mechanism, and government and commercial data as quantitative inputs. One critical issue involves determining when correlations are strictly statistical versus when they result from causal relationships; in the latter case, models can reveal effective interventions. Advances in machine reading and learning, semantic technologies, big data analysis, geo-spatial and economic modeling, and environmental simulation bring this strategic capability within reach. ***FY 2018 Plans:*** - Develop an initial capability to model perturbations having the potential to impact theater security. - Implement automated machine reading and learning techniques for updating large-scale models using public literature and government and commercial data. - Expand large-scale data sets, and initiate evaluations of quantitative models of food security and human migration. - Analyze models of regional and global phenomena, and formulate theory to understand the limits of model accuracy. ***FY 2019 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop advanced capabilities for perturbation modeling and apply technology to additional use cases. - Integrate technologies into initial workflow: build qualitative models, parameterize quantitative models, automate machine processing from scenarios to actions, and generate uncertainty reporting. - Initiate evaluation of integrated technology on food security, human migration, and additional use cases. - Engage stakeholders through demonstration of technologies on a high-priority use case. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development of techniques and software tools to model perturbations having the potential to impact theater security and initial integration of technologies across the envisioned workflow.			
Title: Young Faculty Award (YFA)	17.000	17.000	17.000
Description: The goal of the Young Faculty Award (YFA) program is to encourage junior faculty at universities and their equivalent at non-profit science and technology research institutions to participate in sponsored research programs that will augment capabilities for future defense systems. This program focuses on cutting-edge technologies for greatly enhancing microsystems technologies, biological technologies and defense sciences. The long-term goal for this program is to develop the next generation of scientists, engineers and mathematicians in key disciplines who will focus a significant portion of their careers on DoD and national security issues. The aim is for YFA recipients to receive deep interactions with DARPA program managers, programs, performers and the user community. Current activities include research in fifteen topic areas spanning from Machine Learning and Many Body Physics to Wideband Transmitter-Antenna Interfaces and Multi-Scale Models of Infectious Disease Dynamics. A key aspect of the YFA program is DARPA-sponsored military visits; all YFA Principal Investigators are expected to participate in one or more military site visits to help them better understand DoD needs. ***FY 2018 Plans:*** - Award new FY 2018 grants for new two-year research efforts across the topic areas which established a new set of appropriate technologies to solve current DoD problems. - Continue FY 2017 research on new concepts for microsystem technologies, biological technologies and defense sciences by exercising second year funding, and by providing continued mentorship by program managers. - Award Director's Fellowships for top FY 2016 participants to refine technology further and align to DoD needs. ***FY 2019 Plans:*** - Award new FY 2019 grants for new two-year research efforts across the topic areas which established a new set of appropriate technologies to solve current DoD problems. - Continue FY 2018 research on new concepts for microsystem, biological, strategic, and tactical technologies; information innovation; and defense sciences by exercising second year funding, and by providing continued mentorship by program managers.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Award Director's Fellowships for top FY 2017 participants to refine technology further and align to DoD needs.			
Title: Communicating With Computers (CWC)	14.356	15.000	16.800
Description: The Communicating With Computers (CWC) program is advancing human-computer interaction by enabling computers to comprehend language, gesture, facial expression and other communicative modalities in context. Human language is inherently ambiguous, so humans depend strongly on perception of the physical world and context to communicate. CWC will provide computers with analogous capabilities to sense the physical world, encode the physical world in a perceptual structure, and link language to this perceptual encoding. To accomplish this, CWC will apply and extend research in language, vision, gesture recognition and interpretation, dialog management, cognitive linguistics, and the psychology of visual encoding, which are essential for human communication. CWC will also extend the communication techniques developed for physical contexts to nonphysical contexts such as virtual constructs in the cyber domain. CWC advances will impact military application areas such as robotics and command and control. ***FY 2018 Plans:*** - Develop human-machine communication techniques for a problem solving task in which humans and machines collaborate to explain physical effects. - Develop techniques for learning communication principles and evaluate through at least one use case. - Demonstrate that increased cognitive bandwidth of communication enables machines to collaborate more effectively with humans in solving problems. ***FY 2019 Plans:*** - Enhance techniques to minimize breakdowns in communication in order to maintain natural pacing. - Develop capability for communication that produces content that is interesting and engaging. - Demonstrate integrated capability for one machine or system to seamlessly address multiple use cases. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development of human-computer interaction technologies and expanded work to integrate and demonstrate human-machine communication capabilities.			
Title: Complex Hybrid Systems	3.346	10.500	13.100
Description: This research thrust is focused on exploring fundamental science, mathematics, and computational approaches to collectives, complex hybrid (e.g., human-machine) systems and systems of systems across a variety of DoD-relevant domains. Efforts include development of foundational, quantitative theories and algorithms for the analysis and design of complex systems, as well as novel testing capabilities for assessing the value of these theories using experimental verification across multiple			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
problem domains. Results from this thrust will better enable the systematic design of complex hybrid systems that can achieve unprecedented resilience and adaptability in unexpected environments. ***FY 2018 Plans:*** - Design tools for the measurement and representation of collaborative problem solving performance in human-machine systems and systems-of-systems. - Demonstrate the use of new knowledge representation tools for modeling and optimizing collaborative problem solving performance in human-machine systems and systems-of-systems. - Begin the development of design tools for the optimization of collaborative problem solving performance in human-machine systems and systems-of-systems. - Begin the development of an experimental environment that can test the impact of variation of human-machine system configuration. ***FY 2019 Plans:*** - Continue the development of design tools for the optimization of collaborative problem solving performance in human-machine systems and systems-of-systems. - Continue the development of an experimental environment that can test the impact of variation of human-machine system configuration. - Demonstrate the use of knowledge representation and design tools to produce quantitative explanations of the structure and problem solving strategy of high performing teams with machine elements. - Begin to define foundational principles for design of structures and rules to achieve desired strategic outcomes informed by behavioral, economic, information, and artificial intelligence theory. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects expansion of design tools and testing environments for human-machine systems.			
Title: Building Resource Adaptive Software from Specifications (BRASS)	17.419	17.450	18.373
Description: The Building Resource Adaptive Software from Specifications (BRASS) program is developing an automated framework that permits software systems to seamlessly adapt to changing resource conditions in an evolving operational environment. Effective adaptation is realized through rigorously defined specifications that capture application resource assumptions and resource guarantees made by the environment. The current manual adaptation paradigm is based on corrective patching, which is time-consuming, error-prone and expensive. Predicting the myriad of possible environment changes that an application may encounter in its lifetime is problematic, and existing reactive approaches are brittle and often incorrect. The use of specification-based adaptation will allow BRASS applications to be correctly restructured in real time whenever stated assumptions or guarantees are broken. This restructuring is optimized to trade off execution fidelity and functionality for continued			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
operation. BRASS will create tools to automatically discover and monitor resource changes, build new analyses to infer deep resource-based specifications, and implement compiler and runtime transformations that can efficiently adapt to resource changes. ***FY 2018 Plans:*** - Integrate formal methods techniques to verify correctness of adaptive transformations. - Develop real-time capabilities for dynamically updating software systems in response to resource changes. - Implement program synthesis tools that automatically generate new programs in response to underlying resource changes while maintaining important system invariants. - Design continuous testing frameworks capable of identifying salient resource changes and automatically generating specifications based on test observations. ***FY 2019 Plans:*** - Develop scalable whole-system, resource-aware analysis tools to infer deep resource-based specifications. - Develop optimizing and embeddable compilers to synthesize resource-efficient program variants. - Extend synthesis tools to automatically discover and monitor resource changes for large-scale software systems. - Construct integrated frameworks that automatically permit software systems to seamlessly adapt to changing resource conditions in an evolving operational environment, and demonstrate and evaluate the effectiveness of the adaptation techniques. - Develop techniques to quantify the risk of cyber vulnerabilities in new or existing software systems and enterprise networks. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of development work continuing and additional work to integrate and evaluate the runtime verification and adaptive program transformation techniques.			
Title: Applied Mathematics* ***Description:*** *Formerly Quantifying Uncertainty in Physical Systems The Applied Mathematics thrust will create the basic mathematics needed to support complex analysis ranging from uncertainty quantification to integrated, multi-system design. Focus areas of this thrust include: (1) application of geometry to challenge problems in optimization science; and (2) frameworks and advanced tools for propagating and managing uncertainty in the modeling and design of complex physical and engineering systems. ***FY 2018 Plans:*** - Develop risk-averse stochastic optimization methods to address a complex multi-physics challenge problem and implement the scalable uncertainty quantification (UQ) methods as well as the model error estimates in the optimization framework.	9.000	5.000	4.800

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate the efficacy of UQ methodologies in a final stochastic design problem. - Identify complex, high dimensional, nonlinear, hybrid, stochastic application areas to solve the related optimization problems. - Develop novel tools and algorithms to solve high dimensional non-linear complex optimization problems that cannot be optimized with current methods due to intractability or lack of scalability. - Demonstrate the applicability of novel optimization approaches beyond domain-specific application areas. ***FY 2019 Plans:*** - Advance the developed optimization tools to handle substantial complexity and make working progress towards a fully nonlinear, non-convex problem. - Demonstrate full theoretical and computational development of optimization methodologies with implementation on the real scope/scale application problem. - Initiate work on development of codes and software for the tested optimization algorithms. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects minor program repricing.			
Title: Lifelong Learning Machines (L2M) ***Description:*** The Lifelong Learning Machines (L2M) program will research and develop fundamentally new machine learning mechanisms, enabling machines that learn continuously as they operate. Current learning machines are fully configured in advance of deployment, meaning that they have difficulty accounting for in-the-field mission changes or for unexpected deviations in the data being processed. To overcome this limitation, L2M will pursue learning approaches inspired by biological systems, which continuously learn and improve their skills without losing previous knowledge. Areas of research will include network structures that improve performance by processing new data seen in the field, learn new tasks without forgetting previous tasks, and incorporate context into their understanding of the environment. These capabilities would impact a broad array of military applications that require processing and understanding data in real-time, often have limited data sets for training, and must be deployed in environments where unpredictable events may occur. ***FY 2018 Plans:*** - Identify and define lifelong learning component approaches. - Develop preliminary description of application(s) integrating L2M software components. - Perform first evaluation of lifelong learning software components showing initial capabilities to achieve objectives, using test data set. - Develop plans for how new biological mechanisms will be proven and measured in software, including preliminary specifications of test data. ***FY 2018 to FY 2019 Increase/Decrease Statement:***	-	16.100	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 decrease reflects the program moving to Project ES-02.			
Title: Machine Common Sense (MCS)	-	-	6.200
Description: The Machine Common Sense (MCS) program will explore approaches to commonsense reasoning by machines. Recent advances in machine learning have resulted in exciting new artificial intelligence (AI) capabilities in areas such as image recognition, natural language processing, and two-person strategy games (Chess, Go). But in all of these application domains, the machine reasoning is narrow and highly specialized; broad, commonsense reasoning by machines remains elusive. The program will create more human-like knowledge representations, for example, perceptually-grounded representations, to enable commonsense reasoning by machines about the physical world and spatio-temporal phenomena. Equipping AI systems with more human-like reasoning capabilities will make it possible for humans to teach/correct a machine as they interact and cooperate on tasks, enabling more equal collaboration and ultimately symbiotic partnerships between humans and machines. ***FY 2019 Plans:*** - Develop approaches for machine reasoning about imprecise and uncertain information derived from text, pictures, video, speech, and sensor data. - Design methods to enable machines to identify knowledge gaps and reason about their state of knowledge. - Formulate perceptually-grounded representations to enable commonsense reasoning by machines about the physical world and spatio-temporal phenomena. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.			
Title: Mining and Understanding Software Enclaves (MUSE)	13.000	13.000	-
Description: The Mining and Understanding Software Enclaves (MUSE) program is developing program analyses and frameworks for improving the resilience and reliability of complex software applications at scale. MUSE is applying machine learning algorithms to large software corpora to repair defects and vulnerabilities in existing software, and to create new software programs that conform to desired behaviors and specifications. Specific technical challenges include generation and analysis of persistent semantic artifacts, identification and repair of defects, and inference and synthesis of specifications. MUSE research will improve the security of intelligence-related applications and enhance computational capabilities in areas such as automated code maintenance and revision management, low-level systems implementation, graph processing, entity extraction, link analysis, high-dimensional data analysis, data/event correlation, and visualization. ***FY 2018 Plans:*** - Develop statistical database technologies for scalable feature exploration and mining of the software corpus.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Apply machine learning concepts to predict, repair, and synthesize program properties and structures from purely empirical observations. - Explore the use of both static and dynamic program analyses to discover software anomalies and automatically synthesize program repairs. - Apply natural language processing techniques to discover semantic properties of code from multiple information sources. - Collaborate with potential transition partners to evaluate the effectiveness of the technology on use cases in the areas of automated software synthesis, vulnerability detection, and repair. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Big Mechanism ***Description:*** The Big Mechanism program is creating new approaches to automated computational intelligence applicable to diverse domains such as biology, cyber, economics, social science, and intelligence. Mastering these domains requires the capability to create abstract, causal models from massive volumes of diverse data. Current modeling approaches are heavily reliant on human insight and expertise, but the complexity of these models will soon exceed the capacity for human comprehension. Big Mechanism will create technologies to extract and normalize information for incorporation in flexible knowledge bases; reasoning engines that can infer general rules from a collection of observations; and knowledge synthesis techniques to create models of extreme complexity consistent with huge volumes of data. Big Mechanism applications will accommodate an operator-in-the-loop to clarify ambiguities and reconcile detected inconsistencies. The program has focused on cancer modeling due to the availability of experimental data. The complexity of this problem is representative of challenges facing the DoD in areas such as cyber attribution and open-source intelligence. ***FY 2018 Plans:*** - Apply information extraction techniques developed for the Ras cancer pathway model to other cancer classes, and extend techniques to additional problem domains. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	12.116	4.353	-
Title: Knowledge Representation ***Description:*** The Knowledge Representation thrust will develop much-needed tools to contextualize and analyze heterogeneous scientific data, facilitating field-wide hypothesis generation and testing. This will be accomplished by focusing on two key efforts: (1) the development of domain-agnostic mathematical tools for representing heterogeneous data and (2) the development of domain knowledge in a unified knowledge framework and domain-specific computational tools to embed observable data within	8.000	3.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
the framework and enable tangible discoveries through computational analysis. To demonstrate the applicability of Knowledge Representation technology to multiple complex systems, the thrust will include validation across multiple disparate scientific and engineering fields. The technology developed under this thrust will revolutionize the process of scientific discovery by efficiently maximizing the potential of large, heterogeneous, multi-scale datasets across numerous complex scientific fields. ***FY 2018 Plans:*** - Develop and test mathematical framework for knowledge representation and knowledge extraction. - Demonstrate knowledge and representation tools on multiple domains. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Probabilistic Programming for Advancing Machine Learning (PPAML) ***Description:*** The Probabilistic Programming for Advancing Machine Learning (PPAML) program created an advanced computer programming capability that greatly facilitates the construction of new machine learning applications in a wide range of domains. This capability increases the number of people who can effectively contribute, makes experts more productive, and enables the creation of new tactical applications that are inconceivable given today's tools. The key enabling technology is a radically new programming paradigm called probabilistic programming that enables developers to quickly build generative models of phenomena and queries of interest which a compiler then converts into efficient applications. PPAML technologies were designed for application to a wide range of military domains including Intelligence, Surveillance and Reconnaissance (ISR) exploitation, robotic and autonomous system navigation and control, and medical diagnostics.	7.005	-	-
Accomplishments/Planned Programs Subtotals	145.091	169.069	160.153

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) CYS-01 / *CYBER SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
CYS-01: *CYBER SCIENCES*	-	45.753	41.176	16.251	-	16.251	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Cyber Sciences project supports long term national security requirements through scientific research and experimentation in cyber security. Information technologies enable important new military capabilities and drive the productivity gains essential to U.S. economic competitiveness. Meanwhile, cyber threats grow in sophistication and number, and put sensitive data, classified computer programs, mission-critical information systems, and future economic gains at risk. The basic research conducted under the Cyber Sciences project will produce breakthroughs necessary to enhance the resilience of DoD information systems to current and emerging cyber threats.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Transparent Computing	19.074	16.648	8.911

Description: The Transparent Computing program is developing technologies to enable the implementation of more effective security policies across distributed systems. The scale and complexity of modern information systems obscure linkages between security-related events, making it hard to discover attacks such as advanced persistent threats (APTs). The Transparent Computing program will create the capability to propagate security-relevant information, track complete knowledge of event provenance, and ensure component interactions are consistent with established behavior profiles and policies. Transparent Computing technologies are particularly important for large integrated systems with diverse components such as distributed surveillance systems, autonomous systems, and enterprise information systems.

FY 2018 Plans:

- Incorporate technologies in a comprehensive architectural framework to extend new capabilities across various software layers and systems, with coordination among the different tag-and-track mechanisms.
- Implement detection or enforcement at a network element, such as a firewall, to demonstrate the collection and analysis of causally linked events/activities in near real-time to infer the nature of an attack using realistic APT behavior.
- Conduct an evaluation against a sophisticated, multi-platform APT that uses different lateral movement techniques.

FY 2019 Plans:

- Provide a user interface with tracking and visualization of tagged traffic on the network.
- Implement policy enforcement and enterprise architecture protection capabilities.
- Filter tag streams and information for relevancy without sacrificing precision and accuracy.
- Improve scalability of provenance graph construction, and test and evaluate performance and effectiveness.

FY 2018 to FY 2019 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CYS-01 / *CYBER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 decrease is the result of development work ramping down and the focus shifting to testing and performance evaluation.			
Title: SafeWare ***Description:*** The SafeWare program is developing new code obfuscation techniques for protecting software from reverse engineering. At present, adversaries can extract sensitive information from stolen software, which could include cryptographic private keys, special inputs/failsafe modes, and proprietary algorithms. Today's state-of-the-art in software obfuscation adds junk code (loops that do nothing, renaming of variables, redundant conditions, etc.) that is not resilient against automated tools. Recent breakthroughs in theoretical cryptography have the potential to make software obfuscation into a mathematically rigorous science, very much like what the Rivest-Shamir-Adleman (RSA) algorithm did for the encryption of messages in the 1970s. In its present form, cryptographic obfuscation incurs too much runtime overhead to be practical. The SafeWare program will take this very early-stage obfuscation theory and increase its practicality and efficiency. ***FY 2018 Plans:*** - Develop demonstrations of obfuscation protocols with provable security properties and quantifiable security levels for more complex computational or algorithmic processes. - Create modular approaches that restrict obfuscation to the most sensitive parts of computational or algorithmic processes. - Reformulate classic cryptographic protocols using obfuscation as a basic resource for computational security. ***FY 2019 Plans:*** - Demonstrate obfuscation of sensitive information and algorithms in pattern matching applications in support of cybersecurity and target recognition. - Scale obfuscation methods and demonstrate interoperability of obfuscated software. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is the result of development work concluding and efforts being focused on final demonstrations.	10.319	9.955	3.740
Title: Space/Time Analysis for Cybersecurity (STAC) ***Description:*** The Space/Time Analysis for Cybersecurity (STAC) program is developing techniques to detect algorithmic complexity vulnerabilities and side channel attacks in software. Historically, adversaries have exploited software implementation flaws through buffer and heap overflow attacks. Advances in operating systems have largely mitigated such attacks, so cyber adversaries are now finding new ways of compromising software. Algorithmic complexity and side channel attacks are emerging as a new generation of attacks since they depend on intrinsic properties of software algorithms rather than implementation flaws. The STAC program seeks to develop analysis tools and techniques to detect vulnerabilities to these new attacks in the software which the U.S. government, military, and economy depend.	16.360	14.573	3.600

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
FY 2018 Plans: - Identify the most promising analysis tools for finding vulnerabilities to algorithmic complexity and side channel attacks in a corpus of test programs, and integrate these into a best-of-breed prototype. - Engage in experiments or pilot deployments of prototype tools with transition partners and, based on user feedback, improve prototypes to enhance usability in the context of DoD operational needs. - Implement a unified toolset with latest versions of tools from engagements to allow analysis of complete program modules. ***FY 2019 Plans:*** - Update analysis toolset with latest versions of tools from engagements. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is the result of development work concluding and efforts being focused on final update and delivery of toolsets.			
Accomplishments/Planned Programs Subtotals	45.753	41.176	16.251

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) ES-01 / *ELECTRONIC SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
ES-01: *ELECTRONIC SCIENCES*	-	60.591	86.626	49.546	-	49.546	35.783	34.883	34.883	34.883	-	-

A. Mission Description and Budget Item Justification

The Electronic Sciences project is for basic exploration of electronic and optoelectronic devices, circuits, and processing concepts to meet the military's need for near real-time information gathering, transmission, and processing. In seeking to continue the phenomenal progress in microelectronics innovation that has characterized the last few decades, the project should provide DoD with new, improved, or potentially revolutionary device options for accomplishing these critical functions. The resulting technologies should help maintain knowledge of the enemy, communicate decisions based on that knowledge, and substantially improve the cost and performance of military systems. Research areas include analog, mixed signal, and photonic circuitry for communications and other applications; alternative computer architectures; and magnetic components to reduce the size of Electromagnetic (EM) and sensing systems. Other research could support field-portable electronics with reduced power requirements, ultra-high density information storage "on-a-chip", and new approaches to nanometer-scale structures, molecules, and devices.

Within this project, Beyond Scaling programs will support investigations into materials, devices, and architectures to provide continued improvements in electronics performance with or without the benefit of Moore's Law (silicon scaling). Within the next ten years, traditional scaling will start to encounter the fundamental physical limits of silicon, requiring fresh approaches to new electronic systems. Over the short term, DoD will therefore need to unleash circuit specialization in order to maximize the benefit of traditional silicon. Over the longer term, DoD and the nation will need to engage the computer, material, and mechanical sciences to explore electronics improvements through vertical circuit integration for improved computation or non-volatile memory devices that combine computation and memory. Other memory devices could also leverage an emerging understanding of the physics of magnetic states, electron spin properties, topological insulators, or phase-changing materials. Beyond Scaling programs will address fundamental exploration into each of these areas. The Beyond Scaling programs move to Project ES-02, Beyond Scaling Sciences, in FY 2019.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC)	6.000	5.000	5.000
Description: The High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) program seeks to develop compact Radio Frequency (RF) signal amplifiers for air, ground, and ship-based communications, sensing, and radar systems. HAVOC amplifiers would enable these systems to access the high-frequency millimeter-wave portion of the Electromagnetic (EM) spectrum, facilitating increased range and other performance improvements. Today, the effectiveness of combat operations across all domains increasingly depends on DoD's ability to control and exploit the EM spectrum and to deny its use to adversaries. However, the proliferation of inexpensive commercial RF sources has made the EM spectrum crowded and contested, challenging our spectrum dominance. Operating at higher frequencies, such as the millimeter-wave, helps DoD to overcome these issues and offers numerous tactical advantages such as high data-rate communications and high resolution and sensitivity for radar and sensors. HAVOC will fund basic research in vacuum electronics to improve understanding of the various			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
phenomena governing vacuum electronic amplifiers operating at mm-wave frequencies above 75 GHz. Focus areas will include modeling and simulation techniques, advanced manufacturing methods, novel beam-wave interaction structures, high current density and long-life cathodes, and other relevant topics. Applied research efforts are funded in PE 0602716E, Project ELT-01. ***FY 2018 Plans:*** - Verify and validate the performance of high-fidelity, three-dimensional, multi-physics, numerically efficient modeling and simulation techniques on structures representative of advanced vacuum electronic amplifiers. - Fabricate and test wideband and high-power beam-wave interaction structures, and high current-density cathodes. ***FY 2019 Plans:*** - Demonstrate high-current-density and long life cathodes based on understanding gained from processing and material structure investigations. - Demonstrate wideband and high-power beam-wave interaction structures, and high current-density cathodes.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM)	6.000	5.200	5.400
Description: The Precise Robust Inertial Guidance for Munitions (PRIGM) program aims to identify, investigate, and demonstrate inertial sensor technologies for Positioning, Navigation, and Timing (PNT) in GPS-denied environments. When GPS is not available, these inertial sensors can provide autonomous PNT information. The program will exploit recent advances in integrating photonic (light-manipulating) components into electronics and in employing Microelectromechanical Systems (MEMS) as high-performance inertial sensors for use in extreme environments. Whereas conventional MEMS inertial sensors can suffer from inaccuracies due to factors such as temperature sensitivity, new photonics-based PNT techniques have demonstrated the ability to reject these inaccuracies. PRIGM will focus on two areas. By 2020, it aims to develop and transition a Navigation-Grade Inertial Measurement Unit (NGIMU), a state-of-the-art MEMS device, to DoD platforms. By 2030, it aims to develop Advanced Inertial MEMS Sensors (AIMS) that can provide gun-hard, high-bandwidth, high dynamic range navigation for GPS-free munitions. These advances should enable navigation applications, such as smart munitions, that require low-cost, size, weight, and power inertial sensors with high bandwidth, precision, and shock tolerance. PRIGM will advance state-of-the-art MEMS gyros from TRL-3 devices to a TRL-6 transition platform, eventually enabling the Service Labs to perform TRL-7 field demonstrations. Applied research efforts are funded in PE 0602716E, Project ELT-01, and advanced technology development for the program is budgeted in PE 0603739E, Project MT-15. ***FY 2018 Plans:*** - Integrate component technology and demonstrate photonic-MEMS inertial sensors with beyond-navigation-grade stability and precision.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Test navigation-grade inertial sensor performance robustness to external perturbations such as vibration and shock. ***FY 2019 Plans:*** - Package all component technology and test photonic-MEMS inertial sensor performance robustness to environmental temperature variations and for repeatability between routine operations. - Demonstrate inertial sensor survival and operation through laboratory-representative launch events. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects minor program repricing.			
Title: Signal Processing at RF (SPAR) ***Description:*** The Signal Processing at RF (SPAR) program will investigate advanced analog components to process radio frequency (RF) signals for communications, radar, and electronic warfare applications. Today, electronic components are limited in their ability to distinguish between two or more signals operating at the same frequency when one signal is strong enough to jam the others. The jamming signal, in this case, saturates the receiver electronics much like loud music drowns out a quiet conversation. By using advancements in new semiconductor materials, processing, and novel signal interaction mechanisms, SPAR components will be able to pick out friendly RF signals from both intentional and unintentional jamming signals, even when those signals sit on top of one another in frequency. This capability would enable a range of new applications including communications in contested battlefield RF environments, jamming the RF spectrum while maintaining communication, and full-duplex radio communication. Other potential applications include equipping mobile radios with SPAR-enabled front ends for simultaneous jam-resistant two-way communication and electronic warfare. ***FY 2018 Plans:*** - Perform measurement of SPAR RF signal processing components meeting Phase 1 performance. - Design Phase 2 RF signal processing components with commercial communications grade performance capable of rejecting uncooperative in-band jamming by 30x and cooperative self-interference by 100,000x. ***FY 2019 Plans:*** - Design Phase 3 RF signal processing components with DoD communications grade performance capable of rejecting uncooperative in-band jamming by 100x and cooperative self-interference by 1,000,000x. - Fabricate and integrate the components developed during Phase 2 into a system-level design that extends Simultaneous Transmit And Receive (STAR) capability to Commercial, Off The Shelf (COTS) transceiver technology.	9.000	12.000	11.600

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Perform field measurements on developed STAR system to demonstrate simultaneous bidirectional voice communications over 1 km capable of rejecting uncooperative in-band jamming by 30x and cooperative self-interference by 10,000x while maintaining communications integrity. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects minor program repricing.			
Title: Magnetic Miniaturized and Monolithically Integrated Components (M3IC)	10.000	10.426	10.900
Description: The Magnetic Miniaturized and Monolithically Integrated Components (M3IC) program aims to integrate magnetic components onto semiconductor materials, improving the size and functionality of electromagnetic (EM) systems for communications, radar, and electronic warfare (EW). Current EM systems use magnetic components such as circulators, inductors, and isolators that are bulky and cannot be integrated with electronic circuitry. This limits the utility of the magnetic components as well as their ability to impact overall system performance and function. Reducing the Size, Weight, And Power (SWaP) of magnetic components and integrating them onto semiconductor chips, however, could enable broader exploitation of magnetic materials and provide new mechanisms for the control and manipulation of EM signals. For instance, tighter integration could yield smaller radar systems, higher bandwidth communication over longer ranges, improved jam resistance, and more resilient EW systems. The M3IC program is divided into three technical areas: integration of magnetic materials and systems with semiconductor technology; accurate and efficient modeling of magnetic phenomena from the molecular to the component system level; and exploitation of magnetic phenomena in innovative component designs relevant to DoD EM systems. ***FY 2018 Plans:*** - Characterize properties of magnetic films deposited on semiconductor substrates. - Design and fabricate prototype integrated magnetic components such as circulators and isolators. - Demonstrate prototype modeling codes with improved accuracy and efficiency. - Demonstrate miniaturized and optimized non-linear magnetic components. ***FY 2019 Plans:*** - Demonstrate deposition of high-quality magnetic films greater than 100 microns thick on semiconductor wafers larger than 50 millimeters in diameter. - Characterize properties and evaluate performance of magnetic films. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects minor program repricing.			
Title: A MEchanically Based Antenna (AMEBA)	-	8.000	8.400

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The A MEchanically Based Antenna (AMEBA) program seeks to develop efficient radio frequency (RF) transmitters operating in the Ultra-Low Frequency (ULF) and Very Low Frequency (VLF) ranges, for portable applications in underground and underwater communications. For classical antennas, the minimum antenna size for efficient transmission is related to the wavelength of the RF signal. This fundamental property prevents reducing the size of today's ULF and VLF transmitting antennas, which are up to a mile wide. Whereas traditional antennas generate electromagnetic waves by driving current through a conductive material, AMEBA takes a novel approach, mechanically moving an electrical charge or magnet to generate electromagnetic waves at ULF and VLF. This mechanical coupling provides unique advantages over traditional approaches at these frequencies, most notably greater than 1,000x reduction in antenna size. AMEBA will focus on developing both the materials and precision-controlled electromechanical systems required for an efficient transmitter system. This new capability would enable a range of applications including hard-to-jam wireless communications for use over very long distances and short-range underground and underwater RF links. Other potential applications include terrestrial navigation systems for GPS-denied environments and ground-penetrating radar for detecting unexposed ordnance, underground facilities, and tunnels. ***FY 2018 Plans:*** - Develop physics-based models of the electromagnetic field generation and propagation at targeted distances. - Develop high performance electret and ferroelectric materials able to support high charge density with low charge leakage rates. - Develop ferrofluids with improved magnetization and particle conglomeration properties. - Design and develop electromechanical systems and architectures to realize large scale, high-precision mechanical actuation of magnets and electrically polarized materials. ***FY 2019 Plans:*** - Continue to improve the performance of electric and magnetic materials employed in the program. - Progressively scale mechanical systems to a larger number of elements, synchronously actuated and modulated at RF frequencies. - Demonstrate small, low frequency transmitters capable of text messaging from 10 m underwater or 30 m underground. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects minor program repricing.			
Title: Short Range Independent Microrobotics Program (SHRIMP)	-	-	8.246
Description: The Short Range Independent Microrobotics Program (SHRIMP) will develop microrobots with the ability to clandestinely enter tactical environments and perform close-proximity (within 10cm) functions. These ant-sized microrobots could obtain local sensing data, such as visual, audio, or chemical trace data, whereas similar capabilities today would require hand-placed sensors or not be performed at all. SHRIMP microrobots should be able to self-navigate to an objective location and operate indefinitely from harvested energy. The primary technical developments needed are in the efficiency, robustness,			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
and control of millimeter-scale actuators, which allow the robots to move using new materials, processing, and sensor integration techniques. Recent advances in the strength, efficiency, and robustness of small actuators points to the possibility of efficient land microrobots capable of carrying their power source and traveling nearly 0.5 kilometers on a single battery charge. Successful execution of the SHRIMP program will advance the micro-robotics field, allowing for practical national security applications such as clandestine tactical data collection or strategic communication disruption enabled by colonies of deployed microrobots. ***FY 2019 Plans:*** - Develop and demonstrate actuation mechanisms for microrobot mobility with high power efficiency and sufficient payload capacity. - Prove integration of lightweight control and navigation systems. - Demonstrate integration of robust and efficient modalities for locomotion. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.			
Title: Direct On-Chip Digital Optical Synthesis (DODOS)	7.591	7.000	-
Description: The Direct On-chip Digital Optical Synthesis (DODOS) program will investigate high-performance photonic components for a compact, robust, and highly-accurate optical frequency synthesizer suited to various mission-critical DoD applications. Frequency synthesis and accurate control of radiofrequency and microwave radiation is the enabling technology for radar, satellite and terrestrial communications, positioning and navigation technology, and many other core DoD capabilities. Frequency synthesis and control of light or optical waves, however, has been constrained to laboratory experiments due to the size, fragility, and cost of optical frequency synthesizers. DODOS will leverage recent developments in the field of integrated photonics to enable the development of ubiquitous, low-cost optical frequency synthesizers. The program could lead to disruptive DoD capabilities, including high-bandwidth optical communications, higher performance Light Detection And Ranging (LiDAR), portable high-accuracy atomic clocks, and high-resolution detection of chemical/biological threats at a distance. Applied research for this program is funded within PE 0602716E, Project ELT-01. ***FY 2018 Plans:*** - Develop and implement techniques to improve the laser frequency tuning speed and tuning accuracy using co-integrated electronic and photonic components. - Design components and develop processes for fabrication of high efficiency integrated frequency doublers to reduce the power consumption of the DODOS frequency synthesizer. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 decrease reflects program completion.			
Title: Semiconductor Technology Advanced Research Network (STARNet) ***Description:*** The Semiconductor Technology Advanced Research Network (STARNet) program was a government-industry partnership designed to enable the performance requirements of future sensing, communication, computing, and memory applications. The program sponsored academic research teams focused on technology areas, determined by government and industry experts that impact long-range DoD needs. The sponsored academic research base included approximately 46 universities, 188 faculty researchers, 628 students, and more than 112 industry associate personnel. Industry provided 60% of program funding, while DARPA provided the remaining 40% of funding. STARNet research was divided into three centers that focused on system issues (design architecture and system design) and three centers that focused on device and materials issues (high-performance and low power devices). As the projects in the device and materials centers matured, they were expected to be utilized by the system centers to enhance improvements in system design and fabrication.	18.000	-	-
Title: Near Zero Energy RF and Sensor Operations (N-ZERO) ***Description:*** The Near Zero Power RF and Sensor Operations (N-ZERO) program will investigate the innovative technologies required to extend the lifetimes of remotely-deployed sensors from months to years. Today's state-of-the-art sensors can be pre-placed and remain dormant until awoken by an external trigger or stimulus. However, the active electronics that monitor for external triggers consume power, limiting sensor lifetimes to between weeks and months. N-ZERO seeks to replace these electronics with passive or extremely low-power devices that continuously monitor the environment and wake up active electronics upon detection of a specific trigger. This would eliminate or significantly reduce standby power consumption, ensuring that sensor lifetimes are limited only by the power required to process and communicate confirmed events. In doing so, N-ZERO could enable wireless sensors with drastically increased mission life and help meet DoD's unfulfilled need for a persistent, event-driven sensing capability. To enable this possibility, N-ZERO's basic research component will consider highly innovative sensors and sensor architectures as well as signal processing and digitization technologies with near-zero power consumption. In particular, the program will explore and develop a fundamental understanding of the trade space between power consumption, the minimum detectable signal, and the probability of falsely detecting a trigger. An applied research component is budgeted under PE 0602716E, Project ELT-01.	4.000	-	-
Title: Joint University Microelectronics Program (JUMP) ***Description:*** The Joint University Microelectronics Program (JUMP) is a government-industry joint research program to explore computing, sensing, communication, and data storage innovations for applications beyond the 2030 horizon. The program recognizes that the densely interconnected microsystems of the future will be built through the use of groundbreaking materials, revolutionary devices, advanced architectures, and unconventional computing. JUMP will therefore sponsor academic research teams focused on related key technology areas that will impact future DoD capabilities and national security. The JUMP program	-	18.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
will not only push fundamental technology research but also establish long-range microelectronic research themes with greater emphasis on end-application and systems-level computation. By discovering the science underlying new technologies and overcoming engineering challenges, JUMP will enable DoD applications to exploit the entire electromagnetic spectrum from radio frequency (RF) to terahertz (THz) and to employ both distributed and centralized computing with embedded intelligence and memory. ***FY 2018 Plans:*** - Launch university research teams to study technical areas with long-term impacts to government and industry. - Explore emerging materials, power efficient Radio Frequency (RF), Terahertz (THz), digital, and storage devices for future microsystems. - Investigate distributed and centralized computing architectures and subsystems for efficient information extraction, processing, and autonomous control applications. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to Project ES-02.			
Title: Beyond Scaling - Materials	-	14.000	-
Description: The Beyond Scaling - Materials program will investigate new materials to support next-generation logic and memory components. Historically, the DoD provided leadership in shaping the electronics field through research in semiconductor materials, circuits, and processors. However, as DoD focuses on military-specific components and commercial investments eschew the semiconductor space, U.S. fundamental electronics research is stagnant just as an inflection point in Moore's Law (silicon scaling) is about to occur. The Beyond Scaling - Materials program will pursue potential enhancements in electronics that do not rely on Moore's Law, including research not only into new materials but also into the implications of those materials at the device, algorithm, and packaging levels. These basic explorations include: novel mechanisms for computation based on inherent material properties, new methods to accelerate the identification and utilization of emerging materials, and innovative processes to vertically integrate these materials with others to realize superior computational mechanisms. Applied research for this program is funded within PE 0602716E, Project ELT-01. ***FY 2018 Plans:*** - Begin identifying non-volatile memory solutions that can be integrated on-chip and conduct basic material characterization. - Describe circuit architectures that leverage the unique properties and behaviors of new semiconductor materials. - Demonstrate the capability to fabricate and model stacked logic and memory devices in a single monolithic System on a Chip (SoC) die. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The decrease in FY 2019 reflects the program moving to Project ES-02.			
Title: Beyond Scaling - Architectures and Designs	-	7.000	-
Description: The Beyond Scaling - Architectures and Design program will investigate application-specific circuit architectures that ensure continued improvements in electronics performance with or without the benefit of continued scaling in silicon transistors (Moore's Law). Currently, improvements in electronics largely depend on a regular reduction in the size of silicon components. As Moore's Law slows and the nation loses the benefit of free, exponential improvements in electronics performance, DoD will need to maximize the benefits of available silicon technologies through circuit specialization. This program will investigate the potential for lowering the barriers to designing specialized circuits. Approaches include the use of machine learning and automated design tools to program specialized hardware blocks, integrate them into existing designs, and deploy them in complex systems. Further research would also develop tools to create exact representations of physical hardware. Advances under this program will support a new DoD capability to create specialized hardware and provide benefits by improving electronics systems that do not depend on continued rapid improvements in silicon transistors. Applied research for this program is funded within PE 0602716E, Project ELT-01. ***FY 2018 Plans:*** - Demonstrate a mechanism for organically adapting hardware based on the moment to moment performance requirements of the software being executed. - Design a system block through a machine abstracting the capabilities of a large design team. - Develop software approaches to manage new specialization blocks, which speed up processing for selected applications. - Develop an initial reconfigurable design approach and supporting architectural elements to address classes of big data problems. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to Project ES-02.			
Accomplishments/Planned Programs Subtotals	60.591	86.626	49.546

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) ES-02 / *BEYOND SCALING SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
ES-02: *BEYOND SCALING SCIENCES*	-	0.000	0.000	55.100	-	55.100	55.880	54.390	53.600	53.290	-	-

A. Mission Description and Budget Item Justification

Beyond Scaling Sciences project will support investigations into materials, devices, and architectures to provide continued improvements in electronics performance with or without the benefit of Moore's Law (silicon scaling). Within the next ten years, traditional scaling will start to encounter the fundamental physical limits of silicon, requiring fresh approaches to new electronic systems. Over the short term, DoD will therefore need to unleash circuit specialization in order to maximize the benefit of traditional silicon. Over the longer term, DoD and the nation will need to engage the computer, material, and mechanical sciences to explore electronics improvements through vertical circuit integration for improved computation or non-volatile memory devices that combine computation and memory. Other memory devices could also leverage an emerging understanding of the physics of magnetic states, electron spin properties, topological insulators, or phase-changing materials. Beyond Scaling programs will address fundamental exploration into each of these areas. This Project is not a new start. It aggregates and continues Beyond Scaling programs that were initiated in Projects ES-01 and CCS-02 in this same Program Element.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Beyond Scaling - Materials	-	-	14.000
Description: The Beyond Scaling - Materials program will investigate new materials to support next-generation logic and memory components. Historically, the DoD provided leadership in shaping the electronics field through research in semiconductor materials, circuits, and processors. However, as DoD focuses on military-specific components and commercial investments eschew the semiconductor space, U.S. fundamental electronics research is stagnant just as an inflection point in Moore's Law (silicon scaling) is about to occur. The Beyond Scaling - Materials program will pursue potential enhancements in electronics that do not rely on Moore's Law, including research not only into new materials but also into the implications of those materials at the device, algorithm, and packaging levels. These basic explorations include: novel mechanisms for computation based on inherent material properties, new methods to accelerate the identification and utilization of emerging materials, and innovative processes to vertically integrate these materials with others to realize superior computational mechanisms. Applied research for this program is funded within PE 0602716E, Project ELT-02.			
FY 2019 Plans: - Demonstrate the ability to vertically integrate novel materials for both logic and memory in a monolithic manner in a single System on a Chip (SoC) die. - Demonstrate the basic material properties which would allow for greatly increasing the amount of computational throughput.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate the performance and physics of unconventional components that enable in new circuit topologies and architectures. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project ES-01.			
Title: Beyond Scaling - Architectures and Designs ***Description:*** The Beyond Scaling - Architectures and Design program will investigate application-specific circuit architectures that ensure continued improvements in electronics performance with or without the benefit of continued scaling in silicon transistors (Moore's Law). Currently, improvements in electronics largely depend on a regular reduction in the size of silicon components. As Moore's Law slows and the nation loses the benefit of free, exponential improvements in electronics performance, DoD will need to maximize the benefits of available silicon technologies through circuit specialization. This program will investigate the potential for lowering the barriers to designing specialized circuits. Approaches include the use of machine learning and automated design tools to program specialized hardware blocks, integrate them into existing designs, and deploy them in complex systems. Further research would also develop tools to create exact representations of physical hardware. Advances under this program will support a new DoD capability to create specialized hardware and provide benefits by improving electronics systems that do not depend on continued rapid improvements in silicon transistors. Applied research for this program is funded within PE 0602716E, Project ELT-02. ***FY 2019 Plans:*** - Show the underlying common configurations for optimal hardware which might exist for classes of big data problems. - Study application domains to understand similar sets of mathematical operations, to influence the selection and number of general purpose processors and specialized accelerators. - Explore increased layers of programming abstraction by designing underlying algorithms to recognize patterns of machine instructions that map to available specialized accelerators. - Exploring algorithms and methodologies for quantitative verification of open source Intellectual Property (IP). - Explore the application of machine learning for automated physical design of circuits. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project ES-01.	-	-	7.000
Title: Lifelong Learning Machines (L2M) ***Description:*** The Lifelong Learning Machines (L2M) program will research and develop fundamentally new machine learning mechanisms, enabling machines that learn continuously as they operate. Current learning machines are fully configured in advance of deployment, meaning that they have difficulty accounting for in-the-field mission changes or for unexpected deviations	-	-	16.100

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
in the data being processed. To overcome this limitation, L2M will pursue learning approaches inspired by biological systems, which continuously learn and improve their skills without losing previous knowledge. Areas of research will include network structures that improve performance by processing new data seen in the field, learn new tasks without forgetting previous tasks, and incorporate context into their understanding of the environment. These capabilities would impact a broad array of military applications that require processing and understanding data in real-time, often have limited data sets for training, and must be deployed in environments where unpredictable events may occur. ***FY 2019 Plans:*** - Demonstrate continual learning by determining the ability of artificial intelligence (AI) systems to improve performance while the systems operate, using their current experience as training data. - Design algorithms that can use previous information and generalize it to never before seen situations. - Invent a method that allows a machine learning system to balance adaptability to handling new environments while keeping some previous knowledge that may be important in later stages. - Generate common test data of interest to the government and distribute to performers for validating lifelong learning core capabilities. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project CCS-02.			
Title: Joint University Microelectronics Program (JUMP) ***Description:*** The Joint University Microelectronics Program (JUMP) is a government-industry joint research program to explore computing, sensing, communication, and data storage innovations for applications beyond the 2030 horizon. The program recognizes that the densely interconnected microsystems of the future will be built through the use of groundbreaking materials, revolutionary devices, advanced architectures, and unconventional computing. JUMP will therefore sponsor academic research teams focused on related key technology areas that will impact future DoD capabilities and national security. The JUMP program will not only push fundamental technology research but also establish long-range microelectronic research themes with greater emphasis on end-application and systems-level computation. By discovering the science underlying new technologies and overcoming engineering challenges, JUMP will enable DoD applications to exploit the entire electromagnetic spectrum from radio frequency (RF) to terahertz (THz) and to employ both distributed and centralized computing with embedded intelligence and memory. ***FY 2019 Plans:*** - Expand university research teams to add newly identified technical projects. - Evaluate emerging materials, power efficient radio frequency (RF), terahertz (THz), digital, and storage devices prototype.	-	-	18.000

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Establish novel distributed and centralized computing architectures and subsystems for efficient information extraction, processing, and autonomous control applications. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project ES-01.			
Accomplishments/Planned Programs Subtotals	-	-	55.100

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) MS-01 / *MATERIALS SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
MS-01: *MATERIALS SCIENCES*	-	59.083	75.599	85.569	-	85.569	83.837	85.138	85.138	85.138	-	-

A. Mission Description and Budget Item Justification

The Materials Sciences project provides the fundamental research that underpins the design, development, assembly, and optimization of advanced materials, devices, and systems for DoD applications in areas such as robust diagnostics and therapeutics, novel energetic materials, and complex hybrid systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Molecular Systems and Materials Assembly	24.745	20.290	17.400

Description: The Molecular Systems and Materials Assembly thrust is exploring new approaches for the synthesis, assembly, and characterization of molecules and materials from the atomic to the product scale. Ultimately, materials and methods developed in this thrust will support a wide range of DoD applications that span therapeutics, energetics and next generation optical materials. Specific approaches include non-traditional synthetic approaches such as the use of extreme pressure and/or temperature conditions, engineering and controlling atomic-scale processing routes for designer microstructures, and the synthesis and rapid screening of many molecules to more quickly identify those with desired functions and/or properties. Efforts in this thrust also include assembly of these and other materials, such as subwavelength engineered shapes, into micro-to-macro-scale objects and devices, as well as fundamental studies of the properties and function of these molecular ensembles and systems.

FY 2018 Plans:

- Demonstrate the production of micron and larger feedstocks with nanoscale features and properties.
- Demonstrate unique nanoscale properties for assemblies of micron feedstocks at 1-cm scale or larger.
- Demonstrate rapid discovery of affinity reagents to a series of DARPA-defined challenges, including optimization of binding in a target active site.
- Design, synthesize and transition affinity reagents for current DoD therapeutic or diagnostic challenges with partners such as the U.S. Army Medical Research Institute for Infectious Diseases.
- Begin to investigate new building blocks to form structured materials which have previously unachieved electromagnetic properties.

FY 2019 Plans:

- Demonstrate creation of complex hierarchical structures with nanoscale features and properties.
- Develop methods for the scale-up of nano- and micro-assembly techniques.
- Define limitations associated with scale-up of nano- and micro-assembly processes.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop processing maps that allow for controlling atomic-scale interfaces between grains, precipitates, and defects for two-phase metallic systems. - Begin to investigate designer microstructures, with predefined defect types and structures, that increase a metallic systems strength and/or electrical conductivity over the present state-of-the-art. - Initiate the development of novel multi-scale modeling tools that link atomistic scale to the process scale and allow for the exploration of new metallic systems with unique chemical, mechanical, and electrical properties. - Develop design tools for "meta-atom or meta-molecule" building blocks that can be used to create new material responses to electromagnetic radiation. - Investigate breaking metamolecule symmetry and Lorentz reciprocity to create new material designs. - Develop predictive, parametric models for materials for frequency mixing. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects completion of affinity reagent binding challenge with the Army partner.			
Title: Basic Photon Science	26.173	28.299	20.529
Description: The Basic Photon Science thrust is examining the fundamental science of photons and their interactions in integrated devices for potential DoD-applications such as communications, signal processing, spectroscopic sensing and imaging. One focus area is development of novel, chip-scale optical frequency comb sources and associated technologies for spectroscopic sensing, identification, and quantification of multiple trace materials in spectrally cluttered backgrounds. Additional research will explore development of a complex theoretical framework for maximum information extraction from complex scenes to guide development of new imaging technologies. Work in this thrust will establish the first-principles limits of photon detector performance in a variety of detector technologies to enable better, more sensitive detectors. Finally, the thrust area will explore how distributed networks of low-resolution cameras can capture information compared to a single high-resolution camera. ***FY 2018 Plans:*** - Demonstrate operation of rack-mounted package for mode-locked laser-based optical frequency division microwave source in relevant operational environments. - Demonstrate three dimensional (3D) tabletop sub-wavelength and four-dimensional (4D) imaging of nanostructured technology with nanometer spatial resolution (using tabletop high harmonic x-ray source). - Demonstrate end-user operation of tabletop attosecond source to study electronic and structural dynamics in molecular and semiconductor systems. - Push two-way time and frequency transfer to free-space distances that could advance DoD capabilities. - Develop simulated field test environments for the detection of multiple trace species in a cluttered environment using chip-scale frequency combs in multiple spectral regions.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate cavity-enhanced comb-spectroscopy methods for spectroscopy of multiple trace species in a cluttered environment. - Establish and experimentally verify the fundamental trade space for photon detection and create new designs for photon detectors with significant performance metric improvements. - Evaluate the reconstruction of complex 3D scenes based on factors such as fidelity of reconstruction, size of scene, illumination conditions, reconstruction time and projected size, weight and power requirements. - Begin to experimentally demonstrate and evaluate integrated systems for full complex 3D scene reconstruction from a single viewpoint. - Start to develop a generalized theory for maximum information extraction from all photon pathways. - Determine the fundamental imaging limits and potential information efficiency gains for micro- and nano-scale apertures on the order of one to a few hundred wavelengths. - Investigate very low frequency (VLF) electromagnetic waves for imaging near field disturbances. ***FY 2019 Plans:*** - Compare the fundamental properties of new proof-of-concept detector designs with device performance. - Determine which individual state of the art metrics (efficiency, jitter, bandwidth, and photon number count) are improved by an order of magnitude. - Determine which detector designs result in several state of the art metrics (efficiency, jitter, bandwidth, photon number count) being improved simultaneously by an order of magnitude. - Determine the fundamental requirements and theory (e.g. number of cameras, aperture size, orientation information, resolution, plenoptic variables, etc.) needed for distributed networks of micro- and/or nano-cameras to be able to reconstruct an arbitrary scene. - Design initial small-scale experiments to validate theory and algorithms for scene reconstruction from distributed networks of micro- and/or nano-cameras. - Establish penetration/range/resolution trade space using low frequency electromagnetic waves for imaging. - Demonstrate the possibility of high-resolution imaging in the near field using very low frequency (VLF) detector arrays. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects completion of 3D scene reconstruction activities and final testing of optical spectroscopy methods.			
Title: Fundamental Limits	8.165	22.000	32.090
Description: Understanding the fundamental limits (i.e., achievable boundaries) of scientific principles, processes and technologies is critical to better anticipate technological surprise for our adversaries and ourselves. This thrust explores boundaries across fields such as physics, chemistry, mathematics, biology, and engineering to address critical questions for national security. This thrust is addressing foundational theory and approaches that include, for example, the fundamental			

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
limitations of optical technologies, potential implications for basic biology on national security, leveraging molecular diversity for information storage and processing, and the ability for modeling and simulation to provide a better understanding of complex systems. ***FY 2018 Plans:*** - Demonstrate new design architectures and engineered optical materials on the sub-millimeter (sub-mm) scale. - Develop plans to extend optical device design and fabrication from sub-mm scale to centimeter (cm) scale. - Demonstrate the technical capabilities, both theoretical and experimental, required to definitively determine if electromagnetic signaling is occurring in select biological systems. - Conduct tests of biosystem electromagnetic signaling. - Validate approaches to represent data in molecular form. - Develop strategies to enable direct-access molecular informatics to include integrating elements to directly process molecular data. ***FY 2019 Plans:*** - Design and optimize cm scale optical systems based on engineered materials. - Fabricate and test cm scale engineered material optical components. - Integrate and demonstrate optical systems and architectures based on engineered materials. - Determine if the selected biological systems use electromagnetic signaling to purposefully communicate. - Compare the accuracy and precision of the theoretical signaling predictions with the experimental measurements within and among biological systems. - Quantify information channel capacity and characteristics of the newly discovered communications pathways in selected biological systems. - Demonstrate approaches for reading molecular data, including random access. - Validate molecular processing approaches against relevant computational problems. - Initiate integration of storage and processing approaches to develop a molecular computing concept. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of growth in technologies to anticipate technological surprise and explore boundaries across fields such as physics, chemistry, mathematics, biology, and engineering to address critical questions for national security.			
Title: Non-Equilibrium Materials	-	5.010	15.550
Description: The Non-Equilibrium Materials thrust will explore materials and materials structures that acquire novel properties when driven far from equilibrium. Work in this thrust will examine the physical underpinnings and applications of these systems in areas of interest to the DoD, including next generation electronics, high-performance computing, and sensing. Efforts will include			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
the development of topologically protected excitations in electronic materials and fundamental studies of exotic quantum states of matter in periodically driven solid-state systems. This thrust is an outgrowth from Basic Photon Science. ***FY 2018 Plans:*** - Identify materials that can host nanoscale classical topological excitations for memory, logic, or other applications. - Validate materials that can host quantum topological excitations for topological quantum computing. - Develop techniques for unambiguously measuring and detecting nanoscale topological excitations in electronic systems. - Identify material systems exhibiting novel phenomena when driven far from equilibrium. ***FY 2019 Plans:*** - Establish the presence of topological excitations with size <10 nm at room temperature in a material system. - Demonstrate low power switching of excitations. - Demonstrate the presence of non-Abelian anyon quantum excitations in a material system. - Demonstrate long-term preservation of coherence in a topologically protected qubit. - Develop techniques to prove the properties of material systems driven far from equilibrium. - Demonstrate improved stability of a material property of interest in a periodically driven system. - Validate the existence of novel phases of matter in systems driven out of equilibrium. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects expanded effort to develop and demonstrate the properties of non-equilibrium materials.			
Accomplishments/Planned Programs Subtotals	59.083	75.599	85.569

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) TRS-01 / *TRANSFORMATIVE SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
TRS-01: *TRANSFORMATIVE SCIENCES*	-	46.343	59.877	55.511	-	55.511	57.214	44.221	40.478	29.576	-	-

A. Mission Description and Budget Item Justification

The Transformative Sciences project supports research and analysis that leverages converging technological forces and transformational trends in information-intensive subareas of the social sciences, life sciences, manufacturing, and commerce. The project integrates these diverse disciplines to improve military adaptation to sudden changes in requirements, threats, and emerging/converging trends, especially trends that have the potential to disrupt military operations or threaten National Security. Specific research in this project will investigate technologies to enable detection of novel threat agents (e.g., bacterial pathogens) as well as create innovative materials of interest to the military (e.g., self-healing materials).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Biological Complexity (BioCom)*	11.450	11.500	13.377

Description: *Formerly Understanding Biological Complexity

The Biological Complexity (BioCom) program seeks to enhance the understanding of the basic processes associated with biological network interactions, communication, and control to enable novel approaches and technology development to improve warfighter readiness and military platform resilience. Key advances expected from this research will include the identification of approaches to create stable, predictable, and dynamic control mechanisms of biological networks. Such information will allow the determination of a biosystem's state and enable the prediction of state. Applications range from infectious disease mitigation or prevention, to maintain warfighter health, to predicting and leveraging biological systems for managing communities of microorganisms to prevent biofouling on maritime military systems.

FY 2018 Plans:
- Investigate engineering approaches for influencing the controllability of complex biological systems.
- Investigate the utility of predictive design rules for engineering complex biological systems.
- Assess the feasibility of building engineered controls into biological systems.
- Test candidate engineering approaches relevant to control complex biological systems.
- Establish effective frameworks for independent verification and validation in engineered biological systems.

FY 2019 Plans:
- Develop theoretical and computational approaches to improve design of biological control systems in complex settings.
- Characterize performance and verify specifications of measurement technologies for assessing biological control.
- Build multiple, integrated system-level controllers within complex biological systems.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** TRS-01 / *TRANSFORMATIVE SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Expand the library of well-characterized biological parts relevant to controlling complex biological systems. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects integration of system level controllers and initiation of independent verification and validation (IV&V) efforts.			
Title: Social Simulation (SocialSim) ***Description:*** The Social Simulation (SocialSim) program is developing a computational capability to simulate the spread and evolution of information in the online environment. The global information environment is radically changing how and at what rate information spreads and evolves, and both nation-state and sub-state actors are incorporating messaging into their operations to great advantage. Existing approaches for understanding online information spread and evolution are largely based on specialized exercises that take considerable time to orchestrate and execute, and have limited accuracy. SocialSim aims to enable a deeper and more quantitative understanding of adversaries' messaging campaigns and their likely outcomes, as well as exploration of potential responses. ***FY 2018 Plans:*** - Develop initial modeling and simulation capabilities for the spread and evolution of information in a single online environment. - Develop techniques for ensuring privacy in data assembled for testing simulations. - Develop techniques for testing simulations of online information dynamics using real-world data from a single online environment. ***FY 2019 Plans:*** - Test the capability to simulate online information evolution. - Evaluate the performance of the social simulator in diverse scenarios in a single online environment. - Extend the underlying models and mechanisms to simulate the spread and evolution of information in multiple interconnected online environments. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of development work continuing and technologies being integrated in an initial simulation environment.	5.374	12.451	14.451
Title: Engineered Living Materials (ELM)* ***Description:*** *Formerly Engineering Complex Systems The Engineered Living Materials program will pursue new approaches to engineer complex, multi-cellular systems for enhanced capabilities and functional materials to improve military infrastructure design and logistics. Complex biological materials and	11.495	15.584	14.393

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
systems have unique properties (e.g., controlled porosity and high strength-to-weight ratios) not only because of the inherent components but also because of how those components are assembled together across length scales. Engineering biology tools and techniques are now at a stage to pursue the organization and function of multi-cellular systems for a new class of improved capabilities. This program will develop underlying technological platforms to enable information-driven assembly of hierarchical multi-cellular systems for the development of advanced materials. Advances in this program will impact military approaches to infrastructure design in austere environments as well as established methods for manufacture and maintenance of military platforms (e.g., tanks, planes, ships). ***FY 2018 Plans:*** - Investigate methods for programming cellular behavior in response to external cues. - Develop and test biological systems that have genetically encoded three-dimensional forms of specified dimensions. - Initiate testing of gene expression circuits that confer desirable surface properties and autonomous pattern formation to a multi-cellular community. - Demonstrate methods to join living cells to non-living structural materials for the purpose of creating living building materials. ***FY 2019 Plans:*** - Assess the potential for engineered living materials to respond to damage. - Develop methods to control growth in engineered living materials. - Investigate approaches to propagate external signals over long distances in engineered living materials. - Demonstrate stability over relevant time periods in programmed multi-dimensional shapes. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects a focused assessment and preliminary technology demonstration for a selected portion of methods initially investigated.			
Title: Biology for Security (BIOSEC)	-	11.510	13.290
Description: Based on initial research conducted under the Biological Robustness in Complex Settings (BRICS) program, the Biology for Security program seeks to investigate novel approaches to address the DoD need for rapid detection of unknown and/or emerging biological threats from state actors or violent extremist organizations (VEOs). This program will investigate approaches for identifying pathogens based on specific behaviors, or phenotypes, such as niche finding or cell toxicity. Unlike current methods, which rely on a priori knowledge of the pathogen and cannot detect or otherwise analyze unknown threats, this approach will handle scenarios involving engineered or undiscovered bacterial pathogens that do not have known hallmarks. Advances in this area will produce a completely new capability to assess the emergence of pathogens and to detect pathogens that have been specifically engineered to evade detection by traditional methods. Resulting systems may be used to alert			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** TRS-01 / *TRANSFORMATIVE SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
deployed military personnel operating around the world to new biothreats, or in response to a U.S.-based discovery, outbreak, or pandemic. ***FY 2018 Plans:*** - Investigate new assays for rapid phenotype and pathogenic characterization of organisms or biological systems. - Initiate research to better connect genetic code with biological functions of interest. - Identify new tools that isolate and manipulate small numbers of microbes. ***FY 2019 Plans:*** - Develop assays to rapidly screen organisms or biological systems for traits and mechanisms of interest. - Identify genes and pathways associated with complex biological traits. - Establish the potential for natural or synthetic biological systems as biological threat detectors. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects expansion into correlating genetic code with more complex biological functions.			
Title: Living Foundries	7.100	3.500	-
Description: The goal of the Living Foundries program is to create a revolutionary, biologically-based manufacturing platform for the DoD and the Nation. With its ability to perform complex chemistries, be flexibly programmed through DNA code, scale and adapt to changing environments and self-repair, biology represents one of the most powerful manufacturing platforms known. Living Foundries seeks to develop the foundational technological infrastructure to transform biology into an engineering practice, speeding the biological design-build-test-learn cycle and expanding the complexity of systems that can be engineered. Ultimately, Living Foundries aims to provide game-changing manufacturing paradigms for the DoD, enabling adaptable, on-demand production of critical and high-value molecules. Living Foundries will develop tools to simplify, abstract, and standardize the biological production pathway optimization process. Additionally, Living Foundries will identify the fundamental design rules that govern the construction and organization of underlying genetic elements in the production pathways. Research thrusts include developing the fundamental tools, capabilities, and methodologies to accelerate the biological design-build-test cycle, thereby reducing the extensive cost and time it takes to engineer new systems and expanding the complexity and accuracy of designs that can be built. The result will be rapid design, construction, implementation, and testing of complex, higher-order genetic networks with programmable functionality. Applied research for this program is budgeted in PE 0602715E, Project MBT-02. ***FY 2018 Plans:*** - Demonstrate novel learning systems of microbial systems using integrated feedback of results to inform subsequent designs.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** TRS-01 / *TRANSFORMATIVE SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Utilize improved design and evaluation tools to decrease the cost and increase the speed of biological prototyping. - Demonstrate the capability of new biological chassis for improved yield and production of biochemicals. - Improve the predictability of scaling biological reactions from the lab-scale to the bench-scale. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects completion of basic research efforts.			
Title: Biological Robustness in Complex Settings (BRICS) ***Description:*** The Biological Robustness in Complex Settings (BRICS) program will leverage newly developed technologies to enable radical new approaches for engineering biology. An emerging field, engineering biology is focused on developing the tools to harness the powerful synthetic and functional capabilities of biology. These tools will facilitate design and biological production of new chemicals and materials, sensing capabilities, therapeutics, and numerous other applications. This rapidly developing technological capability opens the door to new applications that have previously been out of reach, and offers substantial potential advantages in terms of cost and novel functionality. Fundamental work in this area will focus on understanding the underlying principles for engineering robust and safe microbes and microbial communities that perform as designed over the long-term. This program has applied research efforts funded in PE 0602715E, Project MBT-02. ***FY 2018 Plans:*** - Continue development of design rules for functional engineered microbial communities. - Refine parameters that contribute to the functional stability of engineered communities over relevant time scales in complex environments. - Develop new metrics that are relevant to the stability and safe use of engineered consortia outside of a controlled environment. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects completion of basic research efforts.	8.924	5.332	-
Title: Open Manufacturing ***Description:*** The Open Manufacturing program will reduce barriers to manufacturing innovation, speed, and affordability of materials, components, and structures. This will be achieved by investing in technologies to enable affordable, rapid, adaptable, and energy-efficient manufacturing, to promote comprehensive design, simulation and performance-prediction tools, and exposure to best practices. The applied research component of this program is funded in PE 0602715E, Project MBT-01 under Materials Processing and Manufacturing.	2.000	-	-
Accomplishments/Planned Programs Subtotals	46.343	59.877	55.511

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** TRS-01 / *TRANSFORMATIVE SCIENCES*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	42.250	43.126	47.825	-	47.825	44.771	47.456	47.456	47.456	-	-
MED-01: *BASIC OPERATIONAL MEDICAL SCIENCE*	-	42.250	43.126	47.825	-	47.825	44.771	47.456	47.456	47.456	-	-

A. Mission Description and Budget Item Justification

The Basic Operational Medical Science Program Element will explore and develop basic research in medical-related information and technology leading to fundamental discoveries, tools, and applications critical to solving DoD challenges. Programs in this project address the Department's identified medical gaps in warfighter care related to health monitoring and preventing the spread of infectious disease. Efforts will draw upon the information, computational modeling, and physical sciences to discover properties of biological systems that cross multiple scales of biological architecture and function, from the molecular and genetic level through cellular, tissue, organ, and whole organism levels. To enable in-theater, continuous analysis and treatment of warfighters, this project will explore multiple diagnostic and therapeutic approaches, including the use of bacterial predators as therapeutics against infections caused by antibiotic-resistant pathogens; developing techniques to enable rapid transient immunity for emerging pathogens; exploring methods to slow damage from pathological infection or traumatic injury; and identifying fundamental biological mechanisms that enable certain species to be tolerant to various environmental insults. Advances in this area may be used as a preventative measure to mitigate widespread disease.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	57.791	43.126	47.882	-	47.882
Current President's Budget	42.250	43.126	47.825	-	47.825
Total Adjustments	-15.541	0.000	-0.057	-	-0.057
• Congressional General Reductions	-6.000	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	-2.374	0.000			
• SBIR/STTR Transfer	-7.167	0.000			
• TotalOtherAdjustments	-	-	-0.057	-	-0.057

Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction, reprogrammings and the SBIR/STTR transfer.
FY 2018: N/A
FY 2019: Decrease reflects minor program repricing.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Analysis and Adaptation of Human Resilience	14.809	10.861	7.055
Description: The Analysis and Adaptation of Human Resilience program will explore new methods to maintain and optimize warfighter health in response to environmental insults such as new and emerging infectious diseases. Research efforts in this area will apply recent advances in comparative biology, genetic sequencing, omics technologies, and bioinformatics to develop new tools for modulating health to ensure warfighter readiness. One approach to achieve this goal is identifying the fundamental mechanisms that enable certain species to be tolerant to various environmental insults. Genomic and physiological analyses of a wide array of resilient animal species may be combined with sophisticated algorithms to identify important patterns of survival. By analyzing patterns in the underlying variability of host responses for resilient animals, one may formulate a survival blueprint to restore and maintain warfighter homeostasis in response to infection. This approach is orthogonal to traditional infectious disease research, which primarily relies on reducing the pathogen load through drug intervention. Research efforts within this program may enable discovery of novel methods to optimize human health against infectious diseases caused by multi-drug resistant pathogens. ***FY 2018 Plans:*** - Screen susceptibility and tolerance to infection in different animal species. - Complete an analysis of the host response to infection in different animal species. - Apply validated algorithms and tools towards the discovery of tolerance mechanisms. - Generate a preliminary set of tolerance-based interventions. ***FY 2019 Plans:*** - Analyze the tolerance response across different animal species, infection models and those discovered in animals using open source human data sets. - Validate tolerance mechanisms in resilient animal models. - Test tolerance-based interventions in susceptible animal models. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is due to the completion of the exploration of tolerance mechanisms and focusing on validation and testing.			
Title: Outpacing Infectious Disease	12.234	16.976	15.616
Description: Military readiness and national security depend on the health and well-being of military service members. Unfortunately, today's antivirals and vaccines are often circumvented by fast-mutating viruses that evolve to develop drug resistance. Military service members often deploy to areas with such diseases that require new protective measures to maintain readiness. The Outpacing Infectious Disease thrust will investigate fundamental methods for using biology as a technology to create adaptive therapeutic response mechanisms to outpace viral diseases such as enabling co-evolution and co-transmission			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
of newly developed therapeutics to ultimately outcompete the pathogen. Key advances expected from this research include identifying methods to discover and develop new classes of dynamic therapeutics for fast-mutating viruses. This approach represents a significant departure from conventional antiviral therapies, which typically rely on static solutions and continuous re-formulation and re-development in attempt to keep pace with emerging strains and disease variants. Advances in this area may be applied to the mitigation of known, new, or emerging diseases that impact military readiness and pose a National Security risk as a potential pandemic. ***FY 2018 Plans:*** - Perform screening, optimization, and generalization of therapeutic interfering particles (TIPs) to other virus cases using dynamic in vitro platforms. - Demonstrate proof of concept TIP co-evolution in vitro. - Initial in vivo assessment of TIP safety and efficacy for selected viruses. - Demonstrate initial proof of concept of TIP efficacy and co-evolution in silico. ***FY 2019 Plans:*** - Apply predictive mathematical models to optimize TIP packaging and mobilization for increased efficacy. - Investigate factors that determine TIP long-term stability. - Evaluate TIPs for selected viruses in relevant animal models of infection. - Optimize TIP production, purification, and scale-up. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects focused effort and evaluation of most promising technologies.			
Title: Preventing the Emergence of Disease (PED)*	-	10.789	15.314
Description: *Formerly Preventing Disease Transmission from Animal Carriers Many emerging infectious disease outbreaks have origins in animal reservoirs and occur in areas where DoD personnel are deployed, putting them at high risk of endemic and emerging diseases. The Preventing the Emergence of Disease (PED) program will investigate how animal pathogens are transmitted to humans and explore novel approaches to prevent these events. Tools such as detailed molecular analysis and bioinformatics will be leveraged. Researchers will develop models to quantify the probability of pathogen disease transmission from animals to humans. Promising intervention approaches will be developed to prevent viral species jumps from animal reservoirs to humans. Predicting such jumps is a key capability to mitigating outbreaks originating in animal reservoirs. ***FY 2018 Plans:***			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Quantify pathogen dynamics in different animal species and environments. - Develop risk models of species jumps for selected viruses using biosurveillance data, geographic location, and animal-animal and/or animal-human interactions. - Integrate molecular and biosurveillance data in initial models to assess potential for animal to human transmission of selected viruses. ***FY 2019 Plans:*** - Develop mathematical models that predict parameters responsible for virus species jump. - Identify approaches to deliver preemptive therapeutics at scale to large populations of animal and/or vector reservoirs. - Establish testbeds to validate model predictions. - Provide proof-of-concept demonstration that preemptive approach reduces the probability of virus jump. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects initiation of framework for multi-location longitudinal sampling.			
Title: Early Battlefield Interventions (EBI) ***Description:*** Based on initial research conducted under the Analysis and Adaptation of Human Resilience program, the Early Battlefield Interventions (EBI) program will explore new methods to slow and limit damage caused by acute trauma and infection often suffered by our warfighters under far-forward conditions. Research efforts will apply advances in molecular and cellular biology, cell signaling, and biomaterials to develop new tools to alter the time course of pathological processes associated with infection and tissue damage. This tactic is a departure from traditional therapeutic approaches that seek to control symptoms associated with active infections or innate physiological responses to tissue trauma. Advances in this area may be applied to the creation of both prophylactic and therapeutic medical countermeasures to forward-deployed service members. ***FY 2018 Plans:*** - Identify new chemical biology methods for reversibly slowing biological processes in cells. - Develop high-throughput testing protocol to evaluate molecular mechanisms of novel approaches. ***FY 2019 Plans:*** - Optimize chemical biology methods to reversibly slow biological processes in cells. - Evaluate safety and efficacy of reversal mechanisms in cells. - Investigate novel delivery methods to successfully implement interventions in multi-cellular systems. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects initiation of a thrust to investigate delivery mechanisms for leading chemical biology methods.	-	4.500	9.840
Title: Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT)	9.107	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT) program will develop the underlying technologies to rapidly respond to a disease or threat and improve individual readiness and total force health protection by providing capabilities which are currently available only in centralized laboratories in the U.S. to non-tertiary care and individual settings. ADEPT will develop and exploit biological tools for the in vivo creation of nucleic acid circuits that continuously and autonomously sense and respond to changes in physiologic state and for novel methods to target delivery, enhance immunogenicity, or control activity of vaccines, potentially eliminating the time to manufacture a vaccine ex vivo. ADEPT advancements to control cellular machinery include research to optimize orthogonality and modularity of genetic control elements; identify methods to increase sensitivity and specificity; and demonstrate methods to control cellular machinery in response to changes in physiological status. ADEPT will develop methodologies for measuring health-specific biomarkers from a collected biospecimen to enable diagnostics at the point-of-need or resource limited clinical facilities (point-of-care), in-garrison or deployed. Additionally, ADEPT will develop techniques that will enable the rapid establishment of transient immunity through stimulation of the production of components of the immune system to impart effective but temporary protection. This transient immunity would bridge the time gap between the delivery of a vaccine and the development of a long term protective immune response. Applied research efforts are budgeted in PE 0602115E, Project BT-01.			
Title: Harnessing Biological Systems ***Description:*** The Harnessing Biological Systems program explored fundamental approaches to applying the advantages of nature's building blocks and principles in the design of biological technologies and systems. Rather than creating biomimetic designs that imitate naturally evolved capabilities this program sought to transition to a biocentric design approach, developing tools and understanding mechanisms to leverage evolutionary advances from the start. Key advances from this research included identifying approaches to discover and develop new classes of dynamic therapeutics for antibiotic-resistant bacteria. One example was the identification of the underlying mechanisms by which predatory bacteria prey upon and consume other antibiotic-resistant bacteria that are pathogenic to humans. This approach represents a significant departure from conventional antibacterial therapies that rely on small molecule antibiotics. Advances in this area may be applied to a range of biological technologies including the autonomous control of epidemics.	6.100	-	-
Accomplishments/Planned Programs Subtotals	42.250	43.126	47.825

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

E. Acquisition Strategy

N/A

F. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	95.801	109.360	101.300	-	101.300	130.831	135.970	138.497	138.497	-	-
BT-01: *BIOMEDICAL TECHNOLOGY*	-	95.801	109.360	101.300	-	101.300	130.831	135.970	138.497	138.497	-	-

A. Mission Description and Budget Item Justification

This Biomedical Technology Program Element focuses on applied research for medical related technology, information, processes, materials, systems, and devices. Successful battlefield medical and neural interface technologies developed within this Program Element address a broad range of DoD challenges to ensure warfighter readiness, including both resilience to infectious disease and neurotechnology for improved warfighter performance. To maintain warfighter health, battlefield medical technologies research in this project will investigate disease forecasting, detection, and therapeutic response. Example projects include a predictive platform for forecasting disease outbreak, identification of early infection biomarkers to diagnose and prevent widespread infection in-theater, new methods to rapidly develop medical countermeasures in response to an emerging biothreat, and in-theater manufacturing capabilities for field-relevant pharmaceuticals to reduce the logistical burden and infrastructure requirements. To improve warfighter performance, this project will develop new neural architectures and data processing algorithms to interface the nervous system with multiple devices, enabling control of robotic prosthetic-limb technology. Additionally, advanced evidence-based techniques will be developed to supplement warfighter healthcare and the diagnosis of post-traumatic stress disorder (PTSD) and traumatic brain injury (TBI).

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	115.213	109.360	153.797	-	153.797
Current President's Budget	95.801	109.360	101.300	-	101.300
Total Adjustments	-19.412	0.000	-52.497	-	-52.497
• Congressional General Reductions	-11.000	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	-2.103	0.000			
• SBIR/STTR Transfer	-6.309	0.000			
• TotalOtherAdjustments	-	-	-52.497	-	-52.497

Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction, reprogrammings and the SBIR/STTR transfer.
FY 2018: N/A
FY 2019: Decrease reflects completion of the Restoration of the Brain Following Trauma and Enhanced Monitoring of Health and Disease programs in FY 2018.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Neuro-Adaptive Technology	19.285	13.500	11.955
Description: The Neuro-Adaptive Technology program will explore and develop advanced technologies for real-time detection and monitoring of neural activity. One shortcoming of today's brain functional mapping technologies is the inability to obtain real-time correlation data that links neural function to human activity and behavior. Understanding the structure-function relationship as well as the underlying mechanisms that link brain and behavior is a critical step in providing real-time, closed-loop therapies for military personnel suffering from a variety of brain disorders. Efforts under this program will specifically examine the networks of neurons involved in post-traumatic stress disorder (PTSD), traumatic brain injury (TBI), depression, and anxiety as well as determine how to best ameliorate these disorders. The objective for this program is to develop new hardware and modeling tools to better discriminate the relationship between human behavioral expression and neural function and to provide relief through novel devices. These tools will allow for an improved understanding of how the brain regulates behavior and will enable new, disorder-specific, dynamic neuro-therapies for treating neuropsychiatric and neurological disorders in military personnel. Technologies of interest under this thrust include devices for real-time detection of brain activity during operational tasks, time synchronized acquisition of brain activity and behavior, and statistical models that correlate neural activity with human behavioral expression. ***FY 2018 Plans:*** - Complete integration of computational model software with prototype device hardware. - Fabricate complete prototype device for use in acute clinical studies. - Submit prototype device design for regulatory approval. - Use prototype device components in clinical patients to demonstrate modulation of disorder-specific psychiatric or neurologic behaviors through real-time, closed-loop stimulation. ***FY 2019 Plans:*** - Utilize clinical data to further refine biomarkers, computational models, and stimulation paradigms for closed-loop modulation of psychiatric or neurologic conditions. - Integrate approaches targeting psychiatric or neurologic conditions with complementary biomarkers, neural targets, and computational models. - Demonstrate use of the prototype neural device in a clinical setting to modulate relevant psychiatric or neurologic function through real-time, closed-loop, biomarker-driven stimulation. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects focused effort for final integration and demonstration.			
Title: Prosthetic Hand Proprioception & Touch Interfaces (HAPTIX)	15.800	15.374	14.985

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: Wounded warriors with amputated limbs get limited benefit from recent advances in prosthetic-limb technology because the user interface for controlling the limb is low-performance and unreliable. Through investments in the DARPA Reliable Neural-Interface Technology (RE-NET) program, novel interface systems have been developed that overcome these issues and are designed to last for the lifetime of the patient. The goal of the Prosthetic Hand Proprioception & Touch Interfaces (HAPTIX) program is to create the first bi-directional (motor & sensory) peripheral nerve implant for controlling and sensing advanced prosthetic limb systems. With a strong focus on transition, the HAPTIX program will create and transition clinically relevant technology in support of wounded warriors suffering from single or multiple limb loss. ***FY 2018 Plans:*** - Validate novel outcome metrics for quantifying effects of sensory prosthetic technologies. - Initiate testing of advanced sensorized prosthetic limbs. - Refine models for sensorimotor function in prosthetic technologies. - Submit technology for regulatory approval. ***FY 2019 Plans:*** - Obtain regulatory approval for HAPTIX technology. - Initiate take-home studies utilizing HAPTIX technology and sensorized prosthetic limbs. - Conduct novel outcome metric testing on HAPTIX amputee participants. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects minor program repricing.			
Title: Performance Optimization in Complex Environments	21.541	19.400	19.485
Description: The Performance Optimization in Complex Environments program will develop neurotechnology to mitigate the effects of physical injury to the auditory and visual systems of military personnel. Research will also focus on understanding various forms of sensing and actuation to improve outcomes and how biofeedback over time can alter human brain function. Technologies developed through this program will provide foundational neural interface technology for restoring lost capability, improving situational awareness, and enhancing cognitive and physical effectiveness. ***FY 2018 Plans:*** - Finalize system designs for highly-scaled input-output of information, and pass a critical design review. - Validate system designs and safety methods against standard regulatory practices. - Conduct a bench demonstration of system components. - Perform in vivo demonstration of input-output techniques for individual neurons.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Produce a neural input/output platform to monitor and modulate large-scale neural activity for a variety of applications relevant to the central nervous system. ***FY 2019 Plans:*** - Refine final validated system designs for prototyping and manufacture. - Demonstrate large-scale read and write capabilities using a fully integrated system. - Develop, harden, and validate security protocols of complete integrated system. - Collect data for the development and refinement of neural decoding and encoding algorithms. - Prepare regulatory documents for therapeutic applications of the brain machine interface. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects minor program repricing.			
Title: Neural Signal Interfaces and Applications (NSIA)*	-	11.140	15.895
Description: *Formerly Generalizing Complex Biological Signals As part of their daily duties, many military personnel must handle large volumes of data and interact with complex systems. These tasks could be made less difficult with advanced neurotechnology platforms, but all such devices currently require invasive surgery to implement. The Neural Signal Interfaces and Applications (NSIA) program will develop non-invasive neurotechnologies able to interface with the nervous system with high resolution and precision without surgery. NSIA will utilize recent advances to transduce neural signals through tissue. Resulting technologies will facilitate standard human-machine interfaces for improved workload balance between man and machine. ***FY 2018 Plans:*** - Develop concepts for noninvasive and minutely invasive sensor/stimulator systems design. - Evaluate neural interface device designs for resolution, stability, and safety aspects. - Initiate research efforts to build required sensors, stimulators, and transducers. ***FY 2019 Plans:*** - Finalize system level design to optimize power usage. - Engineer prototypes of neural interface subcomponents and neural transducers. - Assess neural read and write subcomponents and neural transducers in vitro. - Verify and validate the safety, resolution, and stability of subcomponents. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 increase reflects integration work and advanced engineering.			
Title: Pandemic Prevention	-	17.100	24.985
Description: Military personnel are deployed all over the world for traditional operations, and are often specifically called upon in response to emerging or re-emerging disease outbreaks with pandemic potential (e.g., Ebola). In both instances, the DoD needs effective countermeasures to protect its deployed forces and maintain warfighter readiness. The Pandemic Prevention program will focus on novel methods to rapidly accelerate countermeasure discovery, pre-clinical testing, and manufacturing. This program seeks to advance and integrate newly developed approaches including bioinformatics assessment of genetic sequencing and nucleic acid-based vaccines and to address technology bottlenecks associated with each stage of medical countermeasure development. Additional research will investigate new methods improving the manufacturability, distribution, and delivery of novel therapeutics. Pandemic Prevention will enable an integrated therapeutic development platform that leverages state-of-the-art technologies to prevent disease outbreaks. ***FY 2018 Plans:*** - Develop high-throughput screening technologies to rapidly identify appropriate medical countermeasures against a diversity of biological threats. - Begin developing tools to scale the manufacturability of medical countermeasures. - Initiate development of a validated system for medical countermeasure production. ***FY 2019 Plans:*** - Demonstrate the ability to rapidly discover and mature antibodies against viral infections. - Establish gene-encoded antibody delivery methods in animal models. - Demonstrate protection from pathogen challenge in animal models. - Conduct preliminary demonstration of integrated technologies identifying, maturing, and delivering a gene-encoded antibody to provide protection against viral challenge in animal models. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects integration and multiple technology demonstrations.			
Title: Forensic Indicators of Threat Exposure (FITE)	-	4.750	13.995
Description: Based on initial research conducted under the Enhanced Monitoring of Health and Disease program, the Forensic Indicators of Threat Exposure (FITE) program will develop a field-deployable resource for indicators of an individual's exposure history to Weapons of Mass Destruction (WMD) and WMD precursors. FITE will investigate the ability to characterize epigenetic signatures in an individual's genome caused by specific exposures. The program will create the framework for modular technology capable of performing forensic analysis using epigenetic information to provide high specificity of the type of exposure			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
and when it occurred. This novel capability could serve as a field-forward forensic tool for use by the DoD to assist in chemical, biological, radiological, and nuclear (CBRN) threat detection and response. ***FY 2018 Plans:*** - Define the type of the samples (e.g., blood, serum, plasma, oral and nasal swabs, saliva) to be used for the creation of the epigenetic signature datasets. - Generate candidate datasets to establish a combinatorial epigenetic signature. ***FY 2019 Plans:*** - Identify exposure-specific epigenetic marks that reflect WMD or WMD precursor exposure events. - Validate sensitivity and specificity in representative models. - Create bioinformatics algorithms to decode and characterize differences in the complex epigenetic marks associated with each exposure event. - Initiate development of bioanalytical platform prototype to integrate multiple epigenetic analysis techniques and perform signature analysis. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects integration and advanced engineering of bioanalytical device platform.			
Title: Restoration of Brain Function Following Trauma	17.400	16.316	-
Description: The Restoration of Brain Function Following Trauma program will exploit recent advances in the understanding and modeling of brain activity and organization to develop approaches to treat traumatic brain injury (TBI). Critical to success will be the ability to detect and quantify functional and/or structural changes that occur in the human brain during the formation of distinct new memories, and to correlate those changes with subsequent recall of those memories during performance of behavioral tasks. This program will also develop neural interface hardware for monitoring and modulating neural activity responsible for successful memory formation in a human clinical population. The ultimate goal is identification of efficacious therapeutic approaches that can bypass and/or recover the neural functions underlying memory, which are often disrupted as a consequence of TBI. ***FY 2018 Plans:*** - Refine stimulation parameters to optimize closed-loop, biomarker-driven stimulation for restoration of verbal and spatial memories. - Use an integrated device to demonstrate facilitation of performance on memory tasks through real-time, closed-loop, biomarker-driven stimulation. - Use a computational model of integrated neural, physiological, and environmental signals to quantify the influence of memory replay parameters on subsequent performance of skills relevant to military training and/or operations.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate use of a closed-loop, non-invasive intervention to facilitate neural replay and subsequent performance of skills. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Enhanced Monitoring of Health and Disease ***Description:*** The Enhanced Monitoring of Health and Disease program will improve military health and force readiness by leveraging advanced data collection methods and prognostic capabilities to predict changes in health and spread of infectious disease from the individual to the population scale. While new technology platforms have enhanced our ability to respond to illness and disease, there is a need for predictive and pre-emptive technologies that enable us to correctly prepare a response prior to its obvious need, such as in a barracks or in a confined environment (e.g., submarine). Research in this program will investigate new methods for the collection and detection of multiplexed biological markers as well as the analysis, correlation, and ultimate integration of vast personalized data into the clinical care information technology infrastructure. Additionally, this program will develop new approaches to integrate multi-source data streams to create effective predictive models of disease outbreak and spread. Technologies developed in this program will enable clinically actionable information, even when an individual has no awareness of symptoms, and extend infectious disease forecasting into a real-time, accurate capability for decision support. ***FY 2018 Plans:*** - Select a minimal set of biomarkers that accurately predict contagiousness. - Develop a prognostic assay that predicts contagiousness using the minimal set of biomarkers. - Evaluate models and prognostic tests for accuracy prospectively. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	12.100	9.280	-
Title: Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT) ***Description:*** The overarching goal of the Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT) program is to increase our ability to rapidly respond to a disease or threat and improve individual readiness and total force health protection by providing centralized laboratory capabilities at non-tertiary care settings. ADEPT will focus on the development of Ribonucleic Acid (RNA)-based vaccines, potentially eliminating the time and labor required for traditional manufacture of a vaccine while at the same time improving efficacy. Additionally, ADEPT will develop methods to transiently deliver nucleic acids for vaccines and therapeutics, and kinetically control the timing and levels of gene expression so that these drugs will be safe and effective for use in healthy subjects. ADEPT will also focus on advanced development of key elements for simple-to-operate diagnostic devices. A companion basic research effort is budgeted in PE 0601117E, Project MED-01. ***FY 2018 Plans:***	5.762	2.500	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate safety of gene-encoded antibodies in a dose escalation study against a viral pathogen. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Tactical Biomedical Technologies ***Description:*** The Tactical Biomedical Technologies thrust developed new approaches to deliver life-saving medical care on the battlefield. Uncontrolled blood loss is the leading cause of preventable death for soldiers on the battlefield. While immediate control of hemorrhage is the most effective strategy for treating combat casualties and saving lives, currently no method, other than surgical intervention, can effectively treat intracavity bleeding. A focus in this thrust was the co-development of a materials-based agent(s) and delivery mechanism capable of hemostasis and wound control for non-compressible hemorrhage in the abdominal space, regardless of wound geometry or location within that space. This thrust also investigated non-invasive techniques and equipment to use laser energy to treat intracranial hemorrhage through the skull and tissues in a pre-surgical environment. Finally, in order to address logistical delays associated with delivering necessary therapeutics to the battlefield, this thrust developed a pharmacy on demand that will provide a rapid response capability to enable far-forward medical providers the ability to manufacture and produce small molecule drugs and biologics.	3.913	-	-
Accomplishments/Planned Programs Subtotals	95.801	109.360	101.300

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	341.942	392.784	395.317	-	395.317	376.946	392.956	409.437	404.937	-	-
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	42.442	49.919	55.885	-	55.885	48.613	69.313	80.413	80.413	-	-
IT-03: *INFORMATION ASSURANCE AND SURVIVABILITY*	-	243.642	260.757	259.359	-	259.359	237.491	241.707	239.103	234.603	-	-
IT-04: *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*	-	55.858	82.108	80.073	-	80.073	90.842	81.936	89.921	89.921	-	-

A. Mission Description and Budget Item Justification

The Information and Communications Technology Program Element is budgeted in the Applied Research budget activity because it is directed toward the application of advanced, innovative computing systems and communications technologies.

The High Productivity, High-Performance Responsive Architectures project focuses on developing the computer hardware and associated software technologies required for future computationally- and data-intensive national security applications. Powerful new approaches are needed to manage the rapid growth in available sensor data, to leverage advances in machine learning and artificial intelligence, and to maintain the security of DoD information systems.

The Information Assurance and Survivability project is developing the core computing and networking technologies required to protect DoD's information, information infrastructure, and mission-critical information systems. The technologies will provide cost-effective security and survivability solutions that enable DoD information systems to operate correctly and continuously while under attack, and to be rapidly recovered/reconstituted in the aftermath of an attack.

The Language Understanding and Symbiotic Automation project develops technologies to enable computing systems to understand human speech and extract information contained in diverse media; to learn, reason and apply knowledge gained through experience; to respond intelligently to new and unforeseen events; and to function not only as tools that facilitate human action but as partners to human operators. Enabling computing systems in this manner is of critical importance because sensor, information, and communication systems generate data at rates beyond which humans can assimilate, understand, and act. Incorporating these technologies in military systems will enable warfighters to make better decisions in complex, time-critical, battlefield environments; intelligence analysts to make sense of massive, incomplete, and contradictory information; and unmanned systems to operate safely with high degrees of autonomy.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	353.635	392.784	380.359	-	380.359
Current President's Budget	341.942	392.784	395.317	-	395.317
Total Adjustments	-11.693	0.000	14.958	-	14.958
• 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	3.100	0.000			
• SBIR/STTR Transfer	-14.793	0.000			
• TotalOtherAdjustments	-	-	14.958	-	14.958

Change Summary Explanation

FY 2017: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.

FY 2018: N/A

FY 2019: Increase reflects new start programs addressing artificial intelligence and human-machine collaboration in the Information Assurance and Survivability and Language Understanding and Symbiotic Automation projects.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-02 / *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	42.442	49.919	55.885	-	55.885	48.613	69.313	80.413	80.413	-	-

A. Mission Description and Budget Item Justification

The High Productivity, High-Performance Responsive Architectures project focuses on developing the computer hardware and associated software technologies required for future computationally- and data-intensive national security applications. Powerful new approaches are needed to manage the rapid growth in available sensor data, to leverage advances in machine learning and artificial intelligence, and to maintain the security of DoD information systems. The project therefore aims not only to create larger computing platforms but also to efficiently extract information out of large and chaotic data sets with embedded and low-size, weight, and power systems. Advances in these areas could allow DoD electronic systems to collaboratively manage scarce resources, such as the electromagnetic spectrum, and to adapt to new requirements and situations. Further, the resulting technologies, by being accessible to a wide range of application developers, should help develop new, sustainable computing systems for a broad spectrum of scientific and engineering applications.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Spectrum Collaboration Challenge (SC2)	14.750	18.000	23.885
Description: The Spectrum Collaboration Challenge (SC2) program seeks to catalyze the development of systems, called Collaborative Intelligent Radios (CIRs) that intelligently share and optimize wireless spectrum usage without prior knowledge of each other's operating characteristics. SC2 will address the increasing demand for and reliance on unfettered wireless access. Today, assured access to the wireless spectrum involves restricting particular types of radios and radio operators to certain sets of fixed, pre-determined frequencies. Although this spectrum allocation approach helps ensure different radio signals do not interfere with each other, it is inherently inefficient and vulnerable to attack. First, allocated portions of the spectrum can remain unused or underutilized. Second, adversaries can easily characterize static spectrum allocations, identifying which ones to exploit or attack. SC2 will address this challenge by leveraging artificial intelligence and machine learning to optimize use of the spectrum in real-time. In particular, SC2 participants will be challenged to develop techniques that allow collaboration among dissimilar communications technologies. SC2 will conduct two preliminary competitions and one championship event over three years. The resulting technology will define a new class of radio systems that efficiently thrive in the absence of pre-planned spectrum.			
FY 2018 Plans: - Hold preliminary competition, to take place on the custom-built competition testbed. - Hold second set of qualifying events to select additional Open Track participants.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-02 / *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop visualizations and scoring for large-scale public event. ***FY 2019 Plans:*** - Hold second competition, to take place on the custom-built competition testbed. - Hold third set of qualifying events to select additional Open Track participants. - Develop final competition event execution plan. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects preparation for final competition.			
Title: RF Machine Learning Systems (RFMLS)	-	10.000	23.000
Description: The RF Machine Learning Systems (RFMLS) program will address the performance limitations of conventional radio frequency (RF) systems such as radar, signals intelligence, electronic warfare, or communications. Currently, the capabilities of these systems are fixed at the time of design and limited by their designer's vision. Conversely, a generic RFMLS system would learn how to reconfigure its circuits and processing to meet the requirements of a desired application in a specific environment. The relevant RF features are hand crafted and human specified today, and would instead be learned through machine learning algorithms applied within the RF system itself. The RFMLS system would later learn to adapt to changing conditions and requirements, making a much more robust RF system solution. This flexibility should reduce the time and cost of continually re-designing and upgrading new systems and extend RF system performance beyond the limits of human designers. RMFLS exploits recent advancements in machine learning that have not previously been applied to RF systems. ***FY 2018 Plans:*** - Create datasets and infrastructure for use in training and evaluating RFML Systems. - Begin development of machine learning algorithms and architectures applied to four different challenge problems. - Evaluate integratability of machine learning algorithms and architectures with candidate RF hardware systems. - Identify existing DoD RF systems to upgrade with RFMLS machine learning. ***FY 2019 Plans:*** - Complete development of machine learning algorithms and architectures for two of four challenge problems. - Test preliminary performance of solutions for all four challenge problems and complete final testing for two challenge problem solutions. - Begin development of an RF hardware system to host field testing and demonstrations. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-02 / *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The increase in FY 2019 reflects completing the development of machine learning algorithms and beginning the process of demonstrating machine learning algorithms on a test platform.			
Title: Adversarial AI for RF	-	-	9.000
Description: The Adversarial AI for RF program aims to develop artificial intelligence (AI) capabilities with applications for national security, particularly in areas such as electronic warfare. Given that U.S. and potential adversaries are developing AI technology with potentially revolutionary capabilities, DoD must prepare for conflicts that include offensive and defensive AI actors. Adversarial AI will develop methodologies for protecting AI-enabled DoD systems from adversary attempts to elicit an erroneous response (spoofing) and for significantly increasing AI system reliability and safety. The resulting AI algorithms should also ensure that AI-enabled DoD devices offer human-understandable explanations for their suggested course of action, to the maximum extent possible. To enable this future, the Adversarial AI program will leverage and advance newly formed links between machine learning and security and look to extend these emerging techniques to military specific domains that are emerging such as cognitive Electronic Warfare (EW) systems. Finally, the program may inform the correct mechanism to train AI systems for use in adversarial situations. ***FY 2019 Plans:*** - Specify and bound problem domains, selecting those where the program will have the greatest impact. - Develop new theoretical and algorithmic foundations of lifelong learning cryptographic and waveform attacks and defense. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects program initiation.			
Title: Hierarchical Identify Verify Exploit (HIVE)	16.692	19.919	-
Description: The Hierarchical Identify Verify Exploit (HIVE) program will pursue new hardware architectures and algorithms for rapidly integrating information from a variety of sources, increasing battlefield situational awareness. To develop operationally significant intelligence, human analysts today watch live battlefield feeds to detect items of interest, fusing together and interpreting information from multiple sensors and sources. The amount of information gathered, however, is quickly outstripping the human ability to review, process, fuse, and interpret. To resolve this challenge, HIVE seeks to leverage improvements in machine learning and artificial intelligence to augment the analyst's ability to integrate large streams of data. The program will investigate advances in chip architecture and data analytics algorithms that can allow machines to infer meaning out of data based on the information needs of the warfighter. Program success would therefore enable the warfighter to understand far more of the battlefield in real time. ***FY 2018 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-02 / *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate that the toolsets can be applied to four different classes of DoD problems to include counter terrorism, cyber security, tactical decision making, and intelligence exploitation. - Demonstrate these problems can run on a field programmable gate array which emulate the HIVE chip and measure both power and performance improvements of the proposed design architectures. - Use this information to create a chip design for future fabrication. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to PE 0602716E/ Project ELT-02.			
Title: Electronic Globalization ***Description:*** The Electronic Globalization effort aims to develop advanced capabilities for validating the function of digital, analog, and mixed-signal integrated circuits (IC) given limited design specifications. These ICs are critical to nearly all military systems. Globalization and rapid growth in the commercial electronics industry have limited DoD's ability to influence and regulate IC fabrication. DoD today accounts for a relatively small portion of the overall IC market and the vast majority of IC manufacturing capacity lies overseas. As a result, parts acquired for DoD systems may not meet the stated specifications for performance and reliability. Electronic Globalization will pursue the technologies required to address this and other risks to DoD IC's, such as reverse engineering, counterfeiting, and the theft of U.S. intellectual property. The effort will support the development of key risk-reduction techniques including advanced imaging and computational methods for identifying an IC's functional elements. ***FY 2018 Plans:*** - Continue to study high stress effects on conventionally-fabricated commercial off the shelf (COTS) and government off the shelf (GOTS) electronic components. - Finalize and test models of high stress effects on conventionally-fabricated parts to verify accuracy and tolerances of models. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects program completion.	5.000	2.000	-
Title: Cortical Processor ***Description:*** The Cortical Processor program developed algorithms and hardware that can better handle the increasingly large and diverse sensor data streams used by battlefield systems. By leveraging advances in machine learning, the program yielded systems with the flexibility to understand and adapt to new contexts and new types of sensed data (e.g. new radio frequency or infrared signals). Current sensor platforms, conversely, are pre-programmed only to interpret specific data types and require a laborious coding effort to accommodate new types of data or contexts. Cortical Processor developed hardware implementations that gracefully handle multiple data streams and limit the programming burden required for sensing and interpreting a complex	6.000	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-02 / *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
scenario. The program was enabled by bio-inspired algorithms that benefit from research into biological learning and data processing. Cortical Processor's applied research component investigated silicon circuit designs that are most suitable for high-performance, low-power, real-time sensing and data processing.			
Accomplishments/Planned Programs Subtotals	42.442	49.919	55.885

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	Project (Number/Name) IT-03 / *INFORMATION ASSURANCE AND SURVIVABILITY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
IT-03: *INFORMATION ASSURANCE AND SURVIVABILITY*	-	243.642	260.757	259.359	-	259.359	237.491	241.707	239.103	234.603	-	-

A. Mission Description and Budget Item Justification

The Information Assurance and Survivability project is developing the core computing and networking technologies required to protect DoD's information, information infrastructure, and mission-critical information systems. The technologies will provide cost-effective security and survivability solutions that enable information systems to operate correctly and continuously while under attack, and to be rapidly recovered/reconstituted in the aftermath of an attack. Technologies developed by this project will enable the creation of secure, survivable, network-centric information systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Rapid Attack Detection, Isolation and Characterization Systems (RADICS)	26.500	30.900	34.000

Description: The Rapid Attack Detection, Isolation and Characterization Systems (RADICS) program is developing automated systems to detect attacks on critical U.S. electrical infrastructure, maintain situational awareness of the national power grid, and accelerate the recovery process in the event of an attack. The potential for a cyber-enabled attack on the U.S. power grid is a national security issue, as the ability of the military to deploy and project force is dependent on the effective and efficient functioning of civilian logistics and supply systems. RADICS will develop technologies to monitor heterogeneous distributed networks, detect anomalies that require rapid assessment, isolate compromised system elements, establish secure emergency communications networks, characterize attacks, and detect sensor spoofing. RADICS technology development is coordinated with and will transition to U.S. government elements responsible for defense of critical infrastructure.

FY 2018 Plans:

- Expand prototypes for grid physics anomaly detection, develop capability to detect attempts to spoof Supervisory Control and Data Acquisition (SCADA) telemetry, and incorporate techniques to predict cascading faults across large sections of a power grid.
- Conduct large-scale network experiments to evaluate prototype techniques for forming secure emergency networks.
- Expand prototypes for rapid localization and characterization of cyber attacks targeting industrial control system (ICS) devices and networks to encompass a wider range of equipment and network protocols used in U.S. electrical infrastructure.
- Develop prototype capability to maintain and expand situational awareness in the aftermath of a cyber-enabled attack on the power grid.
- Explore and design techniques to monitor ICS networks for signs of cyber compromise during restart operations.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Conduct simulation-backed exercises to assess the capabilities of prototypes, explore relevant concepts of operation for supporting the recovery of power, and provide potential transition partners with the opportunity to guide prototype refinement. ***FY 2019 Plans:*** - Develop robust capability for grid physics anomaly and SCADA-spoofing detection, and incorporate methods for detecting downstream disturbances caused by malicious manipulations of the bulk power markets. - Develop approaches to augment and optimize the use of available communications links to create ad hoc secure emergency communications networks under conditions of substantial uncertainty. - Develop capability for rapid localization and characterization of cyber weapons targeting a wide range of ICS devices and networks, and develop automated approaches to support cyber first responders in remediation efforts. - Demonstrate capabilities to maintain and expand situational awareness in the aftermath of a cyber-enabled attack on the power grid. - Conduct simulation-backed exercises to evaluate readiness for transition of RADICS tools, engage with potential transition partner personnel to enable them to use the tools in these exercises, and gather feedback on tool effectiveness. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development of technologies for rapid recovery of the power grid from a cyber attack and expanded simulation-backed exercises to establish readiness for transition.			
Title: Dispersed Computing	13.000	17.000	21.800
Description: The Dispersed Computing program is developing techniques to distribute computing tasks across network computing elements to enable more efficient utilization of enterprise and Internet-based storage, processing, and networking resources. At present, enterprises and Internet-based Information Technology (IT) service providers are increasingly adopting the cloud model, with data storage and computer processing concentrated in large data centers, which brings economies of scale and cost savings to storage and processing, but creates problems for the network and for latency-sensitive applications due to the need to backhaul data to (often distant) data centers for processing. The Dispersed Computing program will develop a dispersed computing architecture that results in more efficient utilization of storage, processing, and networking resources. A key enabler is the recent introduction by vendors of network elements that can be dual-purposed as computational elements. These dual-purposed network-compute elements will be used to eliminate bottlenecks/chokepoints, and mitigate impossible backhaul requirements by opportunistically moving code to data given network conditions and available network-compute elements. With Dispersed Computing technology, the network becomes the cloud and computation is performed where it is most efficient to do so. ***FY 2018 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Complete initial prototypes of programmable protocol stacks operating on network-compute elements to boost network transport of code and data. - Tailor protocols to the needs of specific military applications, such as command and control and querying of distributed data stores. - Establish and validate testbeds and instrumentation that enable reliable measurement of program metrics, such as network load reduction and operational scale. - Complete initial prototypes of software control systems to govern access to dispersed network-compute elements, and conduct initial demonstrations of these prototypes to Defense Information Systems Agency (DISA) and their commercial network providers. ***FY 2019 Plans:*** - Incorporate feedback received from demonstrations to refine network-compute element use cases and metrics. - Implement integrated prototype network-compute elements that incorporate dispersed computation algorithms and programmable protocol stack functionality. - Demonstrate and evaluate integrated prototype network-compute elements against program metrics. - Demonstrate integrated network-compute element prototypes to DISA and their commercial network providers. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development of the technologies and software prototypes required to distribute workloads to network-compute elements and expanded demonstrations for potential transition partners.			
Title: Brandeis ***Description:*** The Brandeis program is creating the capability to dynamically, flexibly, and securely share information while ensuring that private data may be used only for its intended purpose and no other. Brandeis will resolve the tension between maintaining privacy and being able to tap into the huge value of data. In the civilian sphere, there is a recognized need for technologies that enable the controlled sharing of information between commercial entities and U.S. government agencies. Similarly, the U.S. military is increasingly involved in operations that require highly selective sharing of data with a heterogeneous mix of allies, coalition partners, and other stakeholders. Brandeis technologies are being designed to work with the virtualization, cloud computing, and software-defined networking technologies now widely used in both civilian and military environments. ***FY 2018 Plans:*** - Develop and demonstrate privacy-preserving information systems using secure multiparty computation, secure database queries, differential privacy, and remote attestation techniques, in which individual and aggregate privacy objectives can be easily understood and implemented consistently. - Demonstrate techniques for confirming that privacy preferences of data owners have been successfully received and honored.	16.000	17.000	20.750

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Work with U.S. government and DoD stakeholders to develop demonstration efforts for privacy-preserving technologies on operational systems. ***FY 2019 Plans:*** - Scale up secure multiparty computation, secure database queries, differential privacy, and remote attestation techniques to U.S. government and DoD data repositories. - Participate in real-world exercises that demonstrate privacy protection in data communication and collaboration on enterprise networks. - Incorporate privacy-preserving technologies in flexible toolkits and transition to U.S. government and DoD transition partners. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of Brandeis development work continuing and the expansion of efforts to demonstrate technologies on U.S. government and DoD use cases.			
Title: Leveraging the Analog Domain for Security (LADS)	20.500	19.700	15.300
Description: The Leveraging the Analog Domain for Security (LADS) program is developing techniques for defending information systems using side channel signals, such as radio frequency and acoustic emissions, power consumption, heat generation, differential fault analysis, and timing-based effects. LADS augments standard cybersecurity approaches, which focus on digital effects/phenomena, with analog techniques. LADS will enable defenders to detect cyber attacks by sensing changes in the analog emissions of computing components, devices, and systems, greatly complicating the task of adversaries who wish to remain hidden. ***FY 2018 Plans:*** - Implement an evaluation framework for Internet of Things (IoT) devices including instrumentation of the platforms and representative test software. - Map selected features from the analog side channels to statistical models to confirm the software running on the device and its state, and identify deviations from the model due to specific attacker behaviors. - Demonstrate feasibility of discriminating between known/unknown code executing on a simple IoT-type device assuming knowledge of the firmware. - Evaluate and enhance the fidelity of the IoT monitor for different IoT devices using the evaluation framework, and explore performance tradeoffs including accuracy and sensor distance. ***FY 2019 Plans:*** - Design antenna arrays and develop signal pre-processing techniques to improve signal-to-noise properties and enable higher-fidelity device monitoring from longer distances against both IoT devices and more complex devices such as thin-clients, feature phones, smart phones, laptops, and servers.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Characterize and model the signals from thin-client, feature phone, smart phone, laptop, and server devices operating in secure/ correct and compromised/faulty states. - Refine side channel models and use them to guide the development of software-based signal boosting techniques. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is the result of development work maturing and the focus shifting to optimization of techniques for use in operational environments.			
Title: Extreme Distributed Denial of Service Defense (XD3) ***Description:*** The Extreme Distributed Denial of Service Defense (XD3) program is developing new computer networking architectures that deter, detect, and overcome Distributed Denial of Service (DDoS) attacks. DDoS attacks include both high-volume flooding attacks and more subtle low-volume attacks that evade traditional intrusion detection systems while exhausting server processing and memory. These attacks will accelerate as the Internet of Things (IoT) incorporates new classes of devices that in many cases will be deployed with inadequate security controls; attackers will assimilate poorly defended IoT devices into their botnets. XD3 will develop defensive architectures that use maneuver, deception, dispersion, and on-host adaptation to increase adversary work factors, boost resilience of mission critical services such as command and control, and ultimately thwart DDoS attacks. ***FY 2018 Plans:*** - Implement and integrate network dispersion, maneuver, and adaptive response techniques in prototype systems that increase adversary work factors in target development, attack planning, and execution. - Test dispersion, maneuver, and adaptive response prototype systems with respect to program metrics. - Conduct exercises in collaboration with transition partners to obtain feedback on XD3 features, capabilities, and concepts of operation. ***FY 2019 Plans:*** - Incorporate feedback received during exercises, and re-test systems against program metrics to verify intended operation and desired transitionable features. - Test within service provider facilities by subjecting XD3 to DDoS attacks as observed in operational network environments. - Pursue transition to commercial network operators and DoD network service providers through demonstrations in their network environments. ***FY 2018 to FY 2019 Increase/Decrease Statement:***	22.800	26.000	12.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 decrease is the result of XD3 development work concluding and the focus shifting to demonstration in operational environments to establish utility for transition partners.			
Title: Cyber Fault-tolerant Attack Recovery (CFAR) ***Description:*** The Cyber Fault-tolerant Attack Recovery (CFAR) program is developing novel architectures to achieve cyber fault-tolerance with commodity computing technologies. The proliferation of processing cores in multi-core central processing units provides the opportunity to adapt fault-tolerant architectures proven in aerospace applications to mission-critical, embedded, and real-time computing systems. The CFAR program will combine techniques for detecting differences across functionally replicated systems with novel variants that exhibit differences in behavior under cyber attack, so that CFAR-enabled computing systems will quickly detect deviations in processing elements at attack onset and rapidly reboot to restore affected services. CFAR technologies will be developed in coordination with operational users. ***FY 2018 Plans:*** - Extend divergence proof system to reason about attacks and prove semantic equivalence of variants produced by the most effective diversity techniques. - Produce a scalable, efficient and potentially deployable capability that can protect a wide range of complex applications. - Refine and integrate test cases, instrumentation, data analysis repositories and tools to support independent evaluation of performance claims. - Assess the performance of components and the integrated CFAR system. ***FY 2019 Plans:*** - Demonstrate an integrated CFAR system that protects against a wide range of threats in an operational environment. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is the result of development work concluding and the focus shifting to demonstration in an operational environment to establish utility for transition partners.	22.500	17.030	5.699
Title: Enhanced Attribution ***Description:*** The Enhanced Attribution program is developing technologies to associate the malicious actions of cyber adversaries to individual operators, and to publicly reveal these actions without compromising sources and methods. The program focuses on new approaches for identifying malicious cyber operators, analyzing their software tools and actions, and confirming this information with commercial and public sources of data. As the attribution techniques are developed and show promise, they will provide the basis for new cyber capabilities such as indications and warning of adversary cyber actions. These technologies will be implemented in tools for evaluation by potential transition partners. ***FY 2018 Plans:***	17.500	21.200	24.530

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Refine and expand the ontology for cyber actions to accommodate new adversary tactics, techniques, and procedures and to reduce the computational and bandwidth requirements of attribution modules. - Integrate attribution modules and demonstrate the capability to generate narrative descriptions of and indications and warning for adversary cyber operator actions. - Conduct evaluations against simulated threats in collaboration with transition partners. ***FY 2019 Plans:*** - Develop and demonstrate algorithmic support for distributed database deployment and query of operational cyber data. - Demonstrate automated narrative generation of adversary cyber operator activities. - Develop metrics that quantify risks to sensitive sources and methods in alternative attribution narratives. - Support transition partners in their evaluation of the attribution technologies. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development of the technologies and expanded evaluation of the software prototypes created to attribute adversary cyber operator actions and to automatically generate attribution narratives.			
Title: Active Social Engineering Defense (ASED)	-	16.000	25.000
Description: The Active Social Engineering Defense (ASED) program, building on technology developed in the Enhanced Attribution program, will develop technologies to automatically identify, disrupt and investigate social engineering attacks via bot-mediated communications. Social engineering attacks, such as phishing and spear-phishing, typically gain user trust via impersonation to induce behaviors or elicit sensitive information that compromise security of an information system. At present, defending against social engineering attacks falls entirely to users. ASED aims to prevent social engineering attacks by creating counter-social-engineering bots that act on behalf of users to mediate and aggregate communications, and auto-identify attackers. If successful, ASED will greatly reduce the effectiveness of adversary social engineering attacks and improve the security of DoD information systems. ***FY 2018 Plans:*** - Develop the means to create synthetic social engineering attack data. - Design a standardized application programming interface to facilitate the integration of counter-social-engineering bot technologies. - Propose algorithms and big data approaches for bots to mediate and aggregate communications, and auto-identify attackers. - Initiate integration of a testbed for evaluating counter-social-engineering bots. ***FY 2019 Plans:*** - Use big data techniques to characterize internet communications and rapidly detect social engineering attacks. - Develop machine-learning-based intelligent bots that can actively engage with attackers.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop initial capability for semi-automated attribution of social engineering attacks. - Assess performance of bot-based techniques to counter social engineering attacks using synthetic data. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of development work accelerating, technologies being integrated in an initial prototype system, and demonstrations on synthetic data.			
Title: Cyber-Hunting at Scale (CHASE)	-	16.800	22.800
Description: The Cyber-Hunting at Scale (CHASE) program will develop data-driven tools for real-time cyber threat detection, characterization, and protection within enterprise-scale networks. U.S. computer networks are continually under attack, but at present no tools exist to efficiently extract the right data from the right device at the right time to analyze these attacks for DoD-scale information networks. For example, analysis of an in-memory exploit would require detailed data from a few devices, while analysis of a global botnet attack would require summary data from millions of devices. CHASE will develop novel algorithms and analysis tools to dynamically collect data from across the network, actively hunt for advanced threats that evade routine security measures, and disseminate protective measures that automatically bolster the collective cyber defense posture. ***FY 2018 Plans:*** - Devise algorithms to process raw packet capture (PCAP), host system log, and netflow data, and construct feature sets for indicators of adversary activity. - Formulate mathematical approaches for managing network sensor data collection, transmission and retention policies to optimize cyber threat detection and characterization, and enhance enterprise-scale cyber situational awareness. - Initiate development of foundational protective measures. - Establish a test and evaluation environment to allow assessment of cyber threat detection and characterization techniques using real-world data. - Develop cyber security techniques for enterprise IT infrastructure. ***FY 2019 Plans:*** - Refine algorithms to process raw and summary cyber data, and construct feature sets for indicators of adversary activity such as credential misuse, data exfiltration, and lateral movement. - Demonstrate improved detection and identification capabilities using closed loop approaches for managing data collection, transmission, and retention. - Perform initial test and evaluation of the most promising cyber threat detection and protective measures through adversarial use cases drawn from real-world datasets including PCAP, host system log, and netflow data. - Demonstrate distributed algorithms to enhance enterprise-scale cyber situational awareness via tests using real-world data.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate cyber security techniques for enterprise IT infrastructure. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of development work accelerating, technologies being integrated in an initial prototype system, and demonstrations using real-world data.			
Title: Cyber Assured Systems Engineering (CASE)	-	17.000	21.400
Description: The Cyber Assured Systems Engineering (CASE) program will develop the design, analysis and verification tools needed to allow system engineers to design-in cyber resiliency and manage tradeoffs as they do other nonfunctional properties when designing complex embedded computing systems. The current state of practice for cyber resilience utilizes penetration testing after system construction to drive post-design re-engineering. The CASE technical approach will be to formulate cyber resilience as an explicitly engineered property, similar to other holistic properties such as safety, durability, and reliability now standard in systems engineering. CASE will focus on the following technical areas: techniques to derive resilience-related requirements before system design and construction; architectural design and analysis tools to design-in the derived resilience requirements while providing feedback to the human designer to allow for informed tradeoffs between resilience and other system design goals; tools to adapt existing software to support system-level resilience requirements; and inference engines, satisfiability solvers, and provers scalable to complex networked cyber physical systems. If successful, CASE technologies will enable the design of cyber physical systems that robustly execute their intended function despite the efforts of sophisticated cyber adversaries. ***FY 2018 Plans:*** - Develop baseline capability to derive resilience-related requirements before system design and construction. - Develop architectural design and analysis tools to verify derived resilience requirements while generating validation tests to run on the eventual implementation. - Develop software analysis tools to verify new resiliency properties in legacy software. - Formulate cyber resilience design challenge problems relevant to military cyber physical systems. ***FY 2019 Plans:*** - Create tools to adapt existing software to support system-level resilience requirements. - Develop techniques for translating the output of cyber resilience design tools into concepts relevant to the system designer. - Enhance inference engines, satisfiability solvers, and provers to scale to complex cyber physical systems. - Demonstrate and evaluate design tools and techniques on an initial cyber resilience design challenge problem. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 increase reflects continued development of techniques and software tools to enable systems engineers to design-in cyber resiliency requirements in a rigorous fashion and initial demonstrations on challenge problems.			
Title: Harnessing Autonomy for Countering Cyber-adversary Systems (HACCS) ***Description:*** The Harnessing Autonomy for Countering Cyber-adversary Systems (HACCS) program, building on technology developed in the Cyber Grand Challenge program, will develop safe and reliable autonomous software agents that can neutralize botnet implants and similar large-scale malware. HACCS will develop technologies to (1) identify and characterize botnet-conscripted networks of devices to determine the types of devices and the software services running on them with sufficient precision to infer the presence of known vulnerabilities; (2) generate software exploits for a large number of known vulnerabilities that can be used to establish initial presence in each botnet-conscripted network without disrupting system functionality; and (3) create high-assurance software agents that autonomously navigate within botnet-conscripted networks, identify botnet implants, and curtail their ability to operate, while minimizing side effects to systems and infrastructure. HACCS will enable U.S. agencies possessing the appropriate authorities to safely conduct Internet-scale counter-botnet operations. ***FY 2018 Plans:*** - Initiate development of algorithms for identifying the command-and-control, attack, and activity traffic of botnet nodes. - Design architecture for automated generation of software exploits using high-level information about known vulnerabilities. - Explore formal approaches to verify correctness properties of autonomous software agents and use machine learning or similar artificial intelligence techniques to ensure safe and reliable autonomous agent behavior. ***FY 2019 Plans:*** - Enhance botnet-tracking algorithms by developing and incorporating techniques to detect stealthy and covert command-and-control protocols. - Scale vulnerability discovery and exploit generation techniques to complex software running on real operating systems. - Collaborate with transition partners to test counter-botnet autonomous agents on synthetic environments, and demonstrate the capability to characterize botnet-conscripted networks in terms of the number, types, and software versions of the compromised devices in those networks. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of development work accelerating, technologies being integrated in an initial prototype system, and demonstrations on synthetic environments.	-	10.727	21.000
Title: Symbiotic Cyber Operations* ***Description:*** *Formerly part of Automated Cyber Operations and Defense (ACOD)	-	4.000	13.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The Symbiotic Cyber Operations program will develop a semi-automated cyber operations system to enable operators to create and analyze cyber effects more rapidly and accurately than unaided human operators. The program envisions high-intensity cyber operations executed by computers under human supervision. To accomplish this, the program will combine automated cyber defense capabilities, such as those developed in DARPA's Cyber Grand Challenge, with human-centric cyber operations planning and execution capabilities, such as those developed under DARPA's Plan X program. This technology will automatically evaluate the defensive posture of software and networks during operations; triage and verify system security issues; determine adversary intent; and guide operator responses. Technologies to be developed and integrated may include binary analysis, case-based reasoning, abstract interpretation, reinforcement learning, game theory, and stochastic optimization. Through human-machine cyber teaming, Symbiotic Cyber Operations will ensure U.S. operational superiority in future cyber conflicts. ***FY 2018 Plans:*** - Initiate development of semantically rich human-computer interfaces for cyber reverse engineering and automated cyber capabilities to analyze defensive security postures. - Develop concepts of operations for mixed-initiative cyber operations. - Create semantic mappings from configuration settings to component functionality, and develop a representation of system functional requirements that enables automated reasoning to evaluate configuration security. ***FY 2019 Plans:*** - Develop a cyber operations reasoning framework to automatically identify which possible actions are allowable under rules of engagement, to rank alternative allowable actions in terms of likely efficacy, and to decide when a proposed action should proceed. - Implement interfaces that facilitate timely human understanding of rapid changes in cyberspace and effective human interaction with automated cyber defenses. - Implement automation modes and logic appropriate for use across the cyber conflict spectrum. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of development work accelerating and technologies being integrated in an initial prototype system.			
Title: Configuration Security* ***Description:*** *Formerly part of Automated Cyber Operations and Defense (ACOD) The Configuration Security program will develop technologies to analyze, monitor, and modify the configuration of composed cyber-physical-human systems to identify system vulnerabilities and minimize the attack surface while maintaining functionality and performance. Complex cyber-physical systems, such as ships, airplanes and critical infrastructure increasingly consist of	-	5.000	14.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
commodity information technology components. The manual configuration necessary to enable each component to interoperate introduces exploitable cyber vulnerabilities, as do the standard operating procedures that system operators follow. The Configuration Security program will develop capabilities to automate the appropriate configuration of such systems within the operational context. The resulting capability will ensure secure configuration settings and prevent malicious changes to these settings. ***FY 2018 Plans:*** - Formulate scalable approaches for generating secure configurations without exhaustive exploration of the configuration space. ***FY 2019 Plans:*** - Develop techniques to automatically generate secure configurations for composed cyber-physical-human systems including the capability to translate human standard operating procedures into machine-understandable formats. - Develop an initial capability to prevent malicious modification of configurations from the system-generated baseline. - Develop algorithms to reconfigure a system automatically to a safer, more secure baseline that assures required functionality. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects expanded algorithm development.			
Title: Protecting C3 Networks (PC3N) ***Description:*** The Protecting C3 Networks (PC3N) program will develop technologies to make military command, control, and communications (C3) networks more resilient against adversary attempts to disrupt, deny, degrade, or destroy mission-critical information, hosts, network elements, or services. PC3N technologies will enable DoD network operators to fully leverage our inherent home field advantage when defending military networks and, ultimately, to neutralize adversary cyber tradecraft in real time. The program will also develop technologies to assure and, when required, restore network integrity in the aftermath of an attack. PC3N technology development will be coordinated with DoD network operators. ***FY 2019 Plans:*** - Develop an analytic framework for quantifying the resilience of a network to adversary attempts to disrupt, deny, degrade, or destroy mission-critical information, hosts, or network elements. - Identify network protocols requiring algorithmic improvements, and develop hardened protocol stacks to ensure delivery of critical services in spite of adversary cyber attacks on C3 networks. - Formulate trusted zeroization and related cryptographic approaches for recovery and assurance of C3 networks in the aftermath of an attack. ***FY 2018 to FY 2019 Increase/Decrease Statement:***	-	-	6.580

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 increase reflects program initiation.			
Title: System Security Integrated Through Hardware and firmware (SSITH)	11.000	18.500	-
Description: The System Security Integrated Through Hardware and firmware (SSITH) program seeks to secure DoD and commercial electronic systems against cybersecurity threats by developing novel hardware/firmware security architectures and hardware design methodologies. Current responses to cybersecurity attacks typically consist of developing and deploying software patches to address specific vulnerabilities in a software firewall without addressing potential vulnerabilities in the underlying hardware architecture. To address this challenge, SSITH will drive new research in electronics hardware security and exploit current research in areas such as cryptographic-based computing and hardware verification. Implementation of these advanced ideas has been enabled by the extremely capable semiconductor technology driven by Moore's Law. The program will also investigate flexible hardware architectures that adapt to and limit the impact of new cybersecurity attacks. Finally, SSITH will seek to mitigate the potential negative impact of new security protection architectures on system performance and power usage. Once developed, SSITH capabilities will be applicable to both commercial and military electronic systems. ***FY 2018 Plans:*** - Utilize modeling and simulation approaches to determine the expected improvement in protection of the new hardware architectures relative to current software only protection. - Establish initial system security metrics and hardware security representations to system security systems. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects the program moving to PE 0602716E, Project ELT-02.			
Title: Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT)	24.938	11.400	-
Description: The Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT) program is developing technologies to enable reliable communications for military forces that operate in the presence of disrupted, degraded or denied wide-area networks. The program is creating algorithms and software prototypes for use exclusively at the network edge, specifically on end hosts and/or on proxy servers fronting groups of such end hosts within a user enclave. EdgeCT systems will sense and respond rapidly to network failures and attacks by dynamically adapting protocols utilized to exchange packets among these hosts, thereby implementing fight-through strategies that restore networked communication. This will enable highly reliable networked communication for the military in the face of a wide variety of common network failure modes as well as cyber attacks against network infrastructure. EdgeCT technologies are being developed in coordination with operational commands. ***FY 2018 Plans:*** - Demonstrate EdgeCT capabilities in overcoming impairments to command and control and related networked applications.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Address and rectify operational vulnerabilities identified by red teams through additional design and testing activities within program testbeds. - Pursue transition to DoD's commercial network operators through demonstrations and testing within service provider facilities, subjecting EdgeCT to impairments observed in network environments. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Plan X ***Description:*** The Plan X program is developing technologies to enable comprehensive awareness and understanding of the cyber battlespace as required for visualizing, planning, and executing military cyber warfare operations. This includes intelligence preparation of the cyber battlespace, indications and warning of adversary cyber actions, detection of cyber-attack onset, cyber-attacker identification, and cyber battle damage assessment. Plan X is creating new graphical interfaces that enable intuitive visualization of events on hosts and networks to aid in the planning and execution of cyber warfare. Plan X will extend operationally meaningful measures to project quantitatively the collateral damage of executed cyber warfare missions. ***FY 2018 Plans:*** - Demonstrate Plan X in transition partner systems. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	23.349	7.500	-
Title: Supply Chain Hardware Integrity for Electronics Defense (SHIELD) ***Description:*** The Supply Chain Hardware Integrity for Electronics Defense (SHIELD) program aims to develop a technology capable of confirming the authenticity of electronic parts at any time and place. Authenticating parts or detecting counterfeit components by current means has proven expensive, time-consuming, and of limited effectiveness. An alternative solution, maintaining complete control of the global supply chain using administrative controls, can also incur substantial costs. SHIELD instead seeks to incorporate a small, inexpensive silicon chip ("dielet") into the packaging of genuine components. The dielet would provide unique and encrypted component identification, enabling authentication from very close proximity. Since counterfeit electronic components pose a threat to the integrity and reliability of both commercial and DoD systems, SHIELD would fulfill a large, pressing, and evolving need for anti-counterfeit technologies. ***FY 2018 Plans:*** - Continue functional and performance testing of manufactured SHIELD dielets. - Demonstrate the SHIELD concept of operation in an actual or environmental facsimile of an integrated circuit supply chain.	16.000	5.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *INFORMATION ASSURANCE AND SURVIVABILITY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Incorporate SHIELD dielets into integrated circuit (IC) packaging and test with a server-connected reader device at various points in the supply chain. - Perform environmental stress and reliability testing on parts with embedded SHIELD dielets to demonstrate that the dielet insertion has no adverse impact on the host IC's performance or reliability. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Vetting Commodity Computing Systems for the DoD (VET) ***Description:*** The Vetting Commodity Computing Systems for the DoD (VET) program developed tools and methods to uncover backdoors and other hidden malicious functionality in the software and firmware on commodity IT devices. The international supply chain that produces the computer workstations, routers, printers, and mobile devices on which DoD depends provides many opportunities for our adversaries to insert hidden malicious functionality. VET technologies detect hidden malicious functionality and also the software and firmware defects and vulnerabilities that can facilitate adversary cyber attack.	12.350	-	-
Title: High Assurance Cyber Military Systems (HACMS) ***Description:*** The High Assurance Cyber Military Systems (HACMS) program developed and demonstrated technologies to secure mission-critical embedded computing systems. The DoD is making increasing use of networked computing in systems such as military vehicles, weapon systems, ground sensors, smartphones, and other communication devices. This dependence makes it critically important that the embedded operating system provides high levels of inherent assurance. This operating system must also integrate the computational, physical, and networking elements of the system while running on a processor with limited size, weight, and power. Consequently, it can only devote a limited share of its computational resources to security while satisfying hard real-time constraints. Recent advances in program synthesis, formal verification techniques, low-level and domain-specific programming languages, and operating systems mean that fully verified operating systems for embedded devices are within reach at reasonable costs. The program developed, matured, and integrated these technologies to produce an embedded computing platform that provides a high level of assurance for mission-critical military applications. Additionally, the program explored the use of formal methods to bring high levels of inherent assurance to Internet-enabled applications, in particular, applications involving remote update, access, management, authorization, and control.	10.300	-	-
Title: Cyber Grand Challenge (CGC) ***Description:*** The Cyber Grand Challenge (CGC) program created automated defenses that identified and responded to cyber attacks more rapidly than human operators. CGC technology monitored defended software and networks during operations, reasoned about flawed software, formulated effective defenses, and deployed defenses automatically. Technologies developed and integrated included anomaly detection, Monte Carlo input generation, case-based reasoning, heuristics, game theory,	6.905	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *INFORMATION ASSURANCE AND SURVIVABILITY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
and stochastic optimization. The CGC capability is needed because highly-scripted, distributed cyber attacks exhibit speed, complexity, and scale that exceed the capability of human cyber defenders to respond in a timely manner. DARPA incentivized competition through a Grand Challenge in which CGC technologies competed head-to-head.			
Accomplishments/Planned Programs Subtotals	243.642	260.757	259.359

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	Project (Number/Name) IT-04 / *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
IT-04: *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*	-	55.858	82.108	80.073	-	80.073	90.842	81.936	89.921	89.921	-	-

A. Mission Description and Budget Item Justification

The Language Understanding and Symbiotic Automation project develops technologies to enable computing systems to understand human speech and extract information contained in diverse media; to learn, reason and apply knowledge gained through experience; to respond intelligently to new and unforeseen events; and to function not only as tools that facilitate human action but as partners to human operators. Enabling computing systems in this manner is of critical importance because sensor, information, and communication systems generate data at rates beyond which humans can assimilate, understand, and act. Incorporating these technologies in military systems will enable warfighters to make better decisions in complex, time-critical, battlefield environments; intelligence analysts to make sense of massive, incomplete, and contradictory information; and unmanned systems to perform critical missions safely and with high degrees of autonomy. The technologies developed in this project will lay the foundation for a new generation of human-machine systems for the U.S. military.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Explainable Artificial Intelligence (XAI)	11.090	18.446	22.000
Description: The Explainable Artificial Intelligence (XAI) program is developing a new generation of machine learning techniques that are able to produce a rationale to explain the conclusions they reach. If current trends continue, future U.S. military autonomous systems will need to perform increasingly complex and sensitive missions, and AI will be critical to such systems. However, in order for developers, users, and senior leaders to feel confident enough to deploy and use AI-enabled systems, these systems must be able to explain their rationale, and their recommendations, decisions, and actions must be delivered in a way that military users can understand and trust. Today, most machine learning systems provide no explanations or provide explanations that are too detailed, at the wrong level of abstraction, or not meaningful to a human user. XAI will develop the tools necessary to build explainable AI systems, in particular (1) new machine learning techniques that produce human-interpretable models and (2) user interfaces that generate explanations from those models meaningful to end-users. XAI implementations will be developed and demonstrated in next-generation autonomous and decision-support systems. ***FY 2018 Plans:*** - Develop and demonstrate an initial prototype using modified deep learning techniques to produce deep neural nets that are more interpretable than current techniques. - Develop and demonstrate an initial prototype using structured, causal, machine learning techniques that are inherently more interpretable.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop and demonstrate an initial prototype that creates an explainable model for an existing black box machine learning system. ***FY 2019 Plans:*** - Formulate second-generation explainable machine learning methods and modified deep learning techniques, and integrate these into prototypes. - Define a set of common test problems in data analytics and autonomous systems for evaluating explanation effectiveness. - Deliver a computational model of the theory of explanation in artificial intelligence, and demonstrate the ability of the computational model to predict the performance of explanations generated by the systems. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development of explainable machine learning techniques and integration for testing on problems in data analytics and autonomous systems.			
Title: Active Interpretation of Disparate Alternatives (AIDA) ***Description:*** The Active Interpretation of Disparate Alternatives (AIDA) program is developing a multi-hypothesis semantic engine that generates alternative interpretations of events, situations, and trends from a variety of unstructured sources for use in environments where there are noisy, conflicting, and potentially deceptive data. At present, information from each medium is often analyzed independently, without the context provided by information from other media, resulting in only one interpretation with alternatives being eliminated due to lack of evidence even in the absence of contradictory evidence. AIDA seeks to develop and demonstrate technology to automatically map information derived from multiple sources into a common semantic representation, aggregate information, resolve ambiguities, discover conflicting information, and generate and explore multiple interpretations of events, situations, and trends. If successful, AIDA will provide decision makers a capability to understand alternative explanations for available information and to make contingency plans accordingly. ***FY 2018 Plans:*** - Define an initial common semantic representation language for diverse sources. - Adapt multimedia-analysis algorithms to produce information suitable for use in a common semantic representation. - Develop semantic techniques that automatically generate, update, rank, and prune alternative interpretations given new data. - Develop techniques to assess the possibility that an interpretation is based on semantically consistent adversarial misinformation. ***FY 2019 Plans:*** - Develop techniques to integrate diverse information from multiple sources into the common semantic representation. - Develop techniques to extend known ontologies using information from diverse sources. - Develop techniques to estimate the confidence of the generated interpretations.	5.500	17.300	21.100

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Evaluate techniques to identify semantically consistent adversarial misinformation on synthetic data. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development of techniques for generating multiple alternative interpretations from multimedia data and conducting adversarial evaluations of techniques on synthetic data.			
Title: Low Resource Languages for Emergent Incidents (LORELEI) ***Description:*** The Low Resource Languages for Emergent Incidents (LORELEI) program is developing technology to rapidly field machine translation and other language processing capabilities for low-resource foreign languages. The U.S. military operates globally and frequently encounters low-resource languages, i.e., languages for which few linguists are available and no automated human language technology capability exists. Processing foreign language materials requires protracted effort, and current systems rely on huge, manually-translated, manually-transcribed, or manually-annotated data sets. As a result, systems currently exist only for languages in widespread use and in high demand. LORELEI takes a different approach by leveraging language-universal resources, projecting from related-language resources, and fully exploiting a broad range of language-specific resources. These capabilities will be exercised to rapidly provide situational awareness based on information from any language in support of emergent missions such as humanitarian assistance/disaster relief, terrorist attack response, peacekeeping, and infectious disease response. ***FY 2018 Plans:*** - Extend development of techniques to determine strength of opinions and beliefs in low-resource language speech as well as text. - Integrate multiple new algorithms with a graphical user interface, and evaluate with end users. - Construct an integrated system employing multiple algorithms for low-resource language analysis. - Evaluate performance on the Uyghur language baseline and on additional low-resource languages. ***FY 2019 Plans:*** - Develop techniques to establish situational awareness from text and speech of low-resource languages. - Extend development of techniques to determine strength of opinions and beliefs to understand urgency and completion status of emerging situations. - Evaluate performance on additional languages, and measure progress on the languages evaluated in the previous year. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is the result of development work concluding and the focus shifting to testing on a diverse collection of low-resource languages.	25.636	28.662	13.880
Title: Assured Autonomy	-	14.700	18.020

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Assured Autonomy program, an outgrowth from the Explainable Artificial Intelligence program, will develop rigorous design and analysis technologies for continual assurance of learning-enabled autonomous systems to guarantee safety properties in uncertain environments. Currently, the state of art for test, evaluation, verification and validation is only applicable to non-learning systems operating in well-characterized environments. As a result, autonomous systems enabled by machine learning (e.g., deep neural nets for perception, reinforcement learning for control policies, and online model learning) lack rigorous safety assurance. Assured Autonomy is developing new techniques for modeling and system design, formal verification, simulation-based testing, machine learning, and safety-assured learning to provide continual assurance of learning-enabled autonomous systems. The technologies being developed in Assured Autonomy will enable the DoD to more rapidly and efficiently deploy learning-enabled autonomous systems that can be trusted to operate safely in uncertain environments. ***FY 2018 Plans:*** - Develop initial algorithms for formal representation and online evaluation of assurance cases, safety-aware learning, and enforcement of safety constraints. - Develop and design verification tools that predict properties and prove correctness of systems with learning-enabled components. - Produce assurance challenge problems for different learning-enabled autonomous systems. ***FY 2019 Plans:*** - Develop techniques and tools that construct formal semantics of assurance cases, provide dynamic interpretation of assurance cases, and modularize and automatically generate assurance cases from system design descriptions. - Develop algorithms that integrate and enforce safety constraints in learning-enabled algorithms. - Apply technologies to several learning-enabled autonomous platforms, and assess their reliability and sensitivity to modeling assumptions. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is the result of the development work accelerating and technologies being tested on several learning-enabled autonomous platforms.			
Title: Human-Machine Symbiosis (HMS)	-	-	5.073
Description: The Human-Machine Symbiosis (HMS) program will develop technologies to enable machines to collaborate with humans as colleagues, partners, and teammates. The world is moving faster than humans can assimilate, understand, and act. At present, we design machines to handle well-defined, high-volume or high-speed tasks, freeing humans to focus on complexity. If successful, HMS technologies will enable machines to do more than execute pre-programmed instructions. Rather, HMS-enabled machines will understand speech; extract information contained in diverse media; learn, reason and apply knowledge gained through experience; identify and work to fill knowledge gaps; extrapolate causal phenomena to anticipate predictable			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
developments; respond intelligently to new and unforeseen events; and exhibit behaviors that are typically believed to require common sense. HMS application areas include cyberspace operations and command and control. ***FY 2019 Plans:*** - Explore meta-knowledge architectures that capture imprecision, uncertainty and errors, identify knowledge gaps, and enable machines to reason about their state of knowledge. - Formulate perceptually-grounded representations to enable commonsense reasoning by machines about the physical world and spatio-temporal phenomena. - Develop quantitative approaches for creating high-performing human-machine teams of individuals and semi-autonomous systems with complementary characteristics/capabilities. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.			
Title: Deep Exploration and Filtering of Text (DEFT) ***Description:*** The Deep Exploration and Filtering of Text (DEFT) program is developing language technology to enable automated extraction, processing, and inference of information from text in operationally relevant application domains. A key DEFT emphasis is to determine explicit and implicit meaning in text through probabilistic inference, anomaly detection, and other techniques. To accomplish this, DEFT will develop and apply formal representations for basic facts, spatial, temporal, and associative relationships, causal and process knowledge, textually entailed information, and derived relationships and correlated actions/events. DEFT inputs may be in English or in specific foreign languages, and sources may be reports, messages, or other documents. DEFT technologies will extract knowledge at scale for open source intelligence and threat analysis. Transition partners include the intelligence community and operational commands. ***FY 2018 Plans:*** - Design and implement an open evaluation with thousands of documents in multiple languages as input, and a single aggregate language-independent knowledge base that includes entities, events, relations, and sentiment as output. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	13.632	3.000	-
Accomplishments/Planned Programs Subtotals	55.858	82.108	80.073

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602383E / *BIOLOGICAL WARFARE DEFENSE*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	20.453	13.014	38.640	-	38.640	44.346	39.346	34.346	34.346	-	-
BW-01: *BIOLOGICAL WARFARE DEFENSE*	-	20.453	13.014	38.640	-	38.640	44.346	39.346	34.346	34.346	-	-

A. Mission Description and Budget Item Justification

The Biological Warfare Defense project is budgeted in the Applied Research Budget Activity because its focus is on the underlying technologies associated with the detection, prevention, treatment and remediation of biological, chemical, and radionuclide threats.

Efforts to counter existing and emerging biological, chemical and radiological threats included: countermeasures to stop the pathophysiologic processes that occur as a consequence of an attack; host immune response enhancers, medical diagnostics for the most virulent pathogens and their molecular mechanisms; collection of environmental trace constituents to support chemical mapping, tactical and strategic biological, chemical, and radiological sensors; and integrated defense systems. This project also includes development of a unique set of platform technologies and medical countermeasures synthesis that will dramatically decrease the timeline from military threat detection to countermeasure availability.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	21.250	13.014	13.469	-	13.469
Current President's Budget	20.453	13.014	38.640	-	38.640
Total Adjustments	-0.797	0.000	25.171	-	25.171
• 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	-0.797	0.000			
• TotalOtherAdjustments	-	-	25.171	-	25.171

Change Summary Explanation

FY 2017: Decrease reflects the SBIR/STTR transfer.

FY 2018: N/A

FY 2019: Increase reflects Defense Against Mass Terror Threats program enhancement to include city-sized simulation detection of multiple classes of Weapons of Mass Destruction threats.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602383E / *BIOLOGICAL WARFARE DEFENSE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Defense Against Mass Terror Threats	13.371	13.014	38.640
Description: The objective of the Defense Against Mass Terror Threats program is to identify and develop technologies that have the potential to significantly improve U.S. ability to reduce the risk of mass casualties in the wake of Weapon of Mass Terror (WMT) attack. Challenges in reducing U.S. vulnerability to these attacks include developing new sensors and systems that afford early warning and opportunities to interdict these threats before they can be employed in urban areas and other population centers. A major goal of this program is to develop new sensors and sensing networks that can economically and reliably provide these wide-area monitoring capabilities for WMT threat signatures. ***FY 2018 Plans:*** - Refine system features and functionality of continuous, wide-area, radiation sensor network based on pilot data collections and user feedback. - Demonstrate, operationalize, and transition full-scale radiation WMT threat monitoring capability with operational partner. - Assess feasibility of generalizing continuous, wide-area, radiation sensing network to monitor beyond radiological and nuclear WMT threats. - Demonstrate integration of chemical WMT sensors into a continuous, wide-area sensing network. - Formalize a cross-discipline multi-path research strategy to realize a holistic detection capability for WMT proliferant activities, actor behaviors, and WMT signatures. ***FY 2019 Plans:*** - Begin process to make an open source, continuous, wide-area sensing platform. - Initiate advanced network algorithms for new sensing modalities and data fusion. - Begin to develop general interfaces to supply advanced WMT monitoring capabilities to existing, operational, and situational awareness systems. - Demonstrate feasibility of continuous sensing network scalability to city-sized areas through simulation for multiple classes of WMT threats, including chemical and biological. - Commence development of advanced adversary prediction models to improve overall system interdiction capabilities. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase is due to investment in identifying and developing technologies beyond nuclear that have the potential to significantly improve U.S. ability to reduce the risk of mass casualties in the wake of Weapon of Mass Terror (WMT) attack.			
Title: Medical Countermeasures	7.082	-	-
Description: The Medical Countermeasures program addressed the safety and efficacy considerations in the risk/benefit package necessary to successfully counter naturally emerging or engineered biological warfare threats and new emerging chemical and radiological threats. These technologies focused on reduction of time, risk, and costs associated with new therapeutic			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602383E / *BIOLOGICAL WARFARE DEFENSE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
development. This program developed in vitro tissue constructs (IVTC) that will emulate human response to therapeutic compounds, thereby significantly reducing the cost and time for evaluating safety and efficacy of therapeutics.			
Accomplishments/Planned Programs Subtotals	20.453	13.014	38.640

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	285.348	343.776	335.466	-	335.466	344.387	316.016	300.376	326.376	-	-
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	32.132	33.544	47.561	-	47.561	54.501	46.451	46.451	41.451	-	-
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	61.166	92.675	112.503	-	112.503	121.283	90.283	64.283	72.283	-	-
TT-06: *ADVANCED TACTICAL TECHNOLOGY*	-	7.269	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
TT-07: *AERONAUTICS TECHNOLOGY*	-	70.367	67.378	59.119	-	59.119	57.678	60.328	62.528	52.528	-	-
TT-13: *INFORMATION ANALYTICS TECHNOLOGY*	-	114.414	150.179	116.283	-	116.283	110.925	118.954	127.114	160.114	-	-

A. Mission Description and Budget Item Justification

The Tactical Technology Program Element is budgeted in the Applied Research Budget Activity because it supports the advancement of concepts and technologies to enhance the next generation of tactical systems. The Tactical Technology program element funds a number of projects in the areas of Naval Warfare, Advanced Land Systems, Advanced Tactical Technology, Aeronautics Technology and Network Centric Enabling Technology.

The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. Enabling and novel technologies include concepts for expanding the envelope of operational naval capabilities such as improved situational awareness over large maritime environments, ship self-defense techniques, novel underwater propulsion modalities, high speed underwater vessels, improved techniques for underwater object detection and discrimination, long endurance unmanned surface vehicles, and high bandwidth communications.

The Advanced Land Systems Technology project is developing technologies for enhancing U.S. military effectiveness and survivability in operations ranging from traditional threats to military operations against irregular forces that can employ disruptive or catastrophic capabilities, or disrupt stabilization operations. The emphasis is on developing affordable technologies that will enhance the military's effectiveness while decreasing the exposure of U.S. or allied forces to enemy fire. This project will also explore novel design technologies for the manufacture of ground vehicles and new tools for systems assessments of emerging DARPA technologies.

The Advanced Tactical Technology project focused on broad technology areas including compact, efficient, frequency-agile, diode-pumped, solid-state lasers for a variety of applications including infrared countermeasures, laser radar, holographic laser sensors, chemical sensing, communications, and high-power laser applications.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*

The Aeronautics Technology project will address high payoff opportunities that dramatically reduce costs associated with advanced aeronautical systems and/or provide revolutionary new system capabilities for satisfying current and projected military mission requirements. This includes advanced technology studies of revolutionary propulsion and vehicle concepts, sophisticated fabrication methods, and examination of novel materials for aeronautic system applications.

The Information Analytics Technology project develops applications for analyzing data and information arising from: 1) intelligence networks; 2) open and other external sources; 3) sensors and signal/image processors; and 4) collection platforms and weapon systems. Technical challenges include the need to process huge volumes of diverse, incomplete, and uncertain data in tactically-relevant timeframes. Efforts address problems related to conditioning of unstructured data, content analysis, behavioral modeling, pattern-of-life characterization, economic activity analysis, social network analysis, anomaly detection, and visualization. Operational benefits include deeper understanding of the evolving operational environment tailored to the needs of commanders at every echelon. Promising technologies are evaluated in the laboratory and demonstrated in the field to facilitate transition.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	313.843	343.776	363.482	-	363.482
Current President's Budget	285.348	343.776	335.466	-	335.466
Total Adjustments	-28.495	0.000	-28.016	-	-28.016
• Congressional General Reductions	-14.000	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	-0.230	0.000			
• SBIR/STTR Transfer	-14.265	0.000			
• TotalOtherAdjustments	-	-	-28.016	-	-28.016

Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction, reprogrammings and the SBIR/STTR transfer.

FY 2018: N/A

FY 2019: Decrease reflects rephasing of several Aeronautics Technology and Information Analytics programs.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-03 / *NAVAL WARFARE TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	32.132	33.544	47.561	-	47.561	54.501	46.451	46.451	41.451	-	-

A. Mission Description and Budget Item Justification

The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. Enabling and novel technologies include concepts for expanding the envelope of operational naval capabilities such as improved situational awareness over large maritime environments, ship self-defense techniques, novel underwater propulsion modalities, vessels for estuary and riverine operations, high speed underwater vessels, improved techniques for underwater object detection and discrimination, long endurance unmanned surface vehicles, and high bandwidth communications.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES)	21.132	33.544	35.561

Description: The Multi-Azimuth Defense Fast Intercept Round Engagement (MAD-FIRES) program seeks to develop a point defense system against today's most stressing threats by developing a highly maneuverable, medium caliber, guided projectile, fire sequencing and control system capable of neutralizing large threat raids of high speed, highly maneuverable targets. Leveraging recent advancements in gun hardening, miniaturization of guided munition components, and long range sensors, MAD-FIRES will advance fire control technologies, medium caliber gun technologies, and guided projectile technologies enabling the multiple, simultaneous target kinetic engagement mission at greatly reduced costs. MAD-FIRES seeks to achieve lethality overmatch through accuracy rather than size, thus expanding the role of smaller combat platforms into missions where they have been traditionally outgunned. MAD-FIRES, sized as a medium caliber system, enhances flexibility for installment as a new system and as an upgrade to existing gun systems with applications to various domain platforms across a multitude of missions to include: ship self-defense, precision air to ground combat, precision ground to ground combat, counter unmanned air vehicles (C-UAV), and counter rocket and artillery and mortar (C-RAM).

FY 2018 Plans:
- Finalize designs for major subcomponents.
- Conduct controlled test vehicle flights.
- Apply lessons learned from flight tests to maturing design.
- Validate sensor modeling and simulation through lab testing.
- Develop advanced algorithms and software for projectile control and threat intercept.

FY 2019 Plans:
- Begin detailed design of system prototype that includes projectile, gun system, and fire control system.
- Update projectile design based on previous year flight test results.
- Validate sensor modeling and simulation through realistic environment testing.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-03 / *NAVAL WARFARE TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Verify projectile compatibility with high speed gun feed system. - Verify fire control system ability to acquire and track surrogate threats. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects minor program repricing.			
Title: Lobster ***Description:*** The undersea domain has significant importance to national security and military operations. Fiber optic cables, military seabed infrastructure, mines, submarines, unmanned vehicles and oil and gas infrastructure are all within this potentially contested environment. Yet it is a challenging domain in which to operate due to extreme water pressures, restricted communications, ever changing bottom environments, marine fouling and corrosion. The Lobster program seeks to improve U.S. operations in this domain by enabling underwater robotic systems significantly ahead of the state of the art. These robotic systems would be able to execute inspection, characterization, repair, manipulation, recharging, data exfiltration, re-tasking and other high value services without the need for continuous human control and high risk surface ship launch and recovery. Key Lobster technical challenges include scene recognition through visual and acoustic modalities, autonomous behaviors, environmental robustness, vehicle endurance, universality for all unmanned underwater systems, energy storage and interaction with the maritime domain. The anticipated transition is to the Navy. ***FY 2019 Plans:*** - Conduct exploratory trade studies to establish feasibility of technical approaches. - Initiate studies on integration within unmanned underwater vehicle system architecture. - Conduct a logistics study to determine vehicle support approaches. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.	-	-	12.000
Title: Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV) ***Description:*** The Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV) program had three primary goals: (1) to build and demonstrate an experimental unmanned vessel with beyond state-of-the-art platform performance based on clean sheet design for unmanned operation; (2) demonstrate the technical viability of operating autonomous unmanned craft at theater or global ranges, from forward operating bases, under a sparse remote supervisory control model; and (3) leverage unique ACTUV characteristics to transition a game changing ASW capability to the Navy. When coupled with innovative sensor technologies, the ACTUV system provided a low cost unmanned system with a fundamentally different operational risk calculus that enables game changing capability to detect and track even the quietest diesel electric submarine threats. Key technical areas included unmanned naval vessel design methodologies, ship system reliability, high fidelity sensor fusion to provide an accurate	6.000	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-03 / *NAVAL WARFARE TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
world model for autonomous operation, novel application of sensors for ASW tracking, and holistic system integration due to unique optimization opportunities of the ACTUV system.			
Title: Upward Falling Payloads (UFP) ***Description:*** The Upward Falling Payloads (UFP) program developed forward-deployed unmanned distributed systems to provide non-lethal effects or situational awareness over large maritime environments. The UFP approach centered on pre-deploying deep-ocean nodes years in advance in forward operating areas which could be commanded from standoff to launch to the surface.	5.000	-	-
Accomplishments/Planned Programs Subtotals	32.132	33.544	47.561

C. Other Program Funding Summary ($ in Millions)

Line Item	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
• ACTUV: *Office of Naval Research MOA*	8.807	3.917	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	61.166	92.675	112.503	-	112.503	121.283	90.283	64.283	72.283	-	-

A. Mission Description and Budget Item Justification

The Advanced Land Systems Technology project is developing technologies for enhancing U.S. military effectiveness and survivability in operations ranging from traditional threats to military operations against irregular forces that can employ disruptive or catastrophic capabilities, or disrupt stabilization operations. The emphasis is on developing affordable technologies that will enhance the military's effectiveness while decreasing the exposure of U.S. or allied forces to enemy fire. This project will also explore novel design technologies for the manufacture of ground vehicles and new tools for systems assessments of emerging DARPA technologies.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Squad X	30.410	36.675	28.503

Description: The U.S. military achieves overmatch against its adversaries in certain regimes; however, this level of overmatch is not enjoyed at the squad to individual dismounted warfighter level. The goal of the Squad X program is to leverage advances in real-time situational awareness and mission command; organic three-dimensional dismount mobility; extended range tracking, targeting, and response; and unmanned mobility and perception in order to create a squad with substantial combat overmatch. The concept of overmatch at the squad level includes increased human stand-off, a smaller force density, and adaptive sensing to allow for responses at multiple scales. Squad X will explore advanced wearable force protection, advanced organic squad level direct and indirect trajectory precision weaponry, and non-kinetic precision capabilities. The end result of the Squad X program is an individual dismount unit outfitted with sensors, weaponry, and supporting technology to achieve unit level overmatch as well as the overall integration of unmanned assets alongside the dismounts to create an advanced, dismounted small unit.

FY 2018 Plans:

- Demonstrate and complete development of individual technology capabilities for squad precision effects, non-kinetic engagement, enhanced sensor fusion and exploitation, and squad collaborative autonomy in simulated operational environments.
- Continue technology development efforts focusing on human machine interfaces, the squad common operating picture in two dimensions, and the synchronization of kinetic and non-kinetic engagement capabilities.
- Continue squad-system development efforts focusing on an automatic, augmenting system to increase squad performance and the integration of previously developed technology to enhance dismounted operations.
- Conduct system-level experimentation and evaluation in relevant conditions with operational units.

FY 2019 Plans:

- Complete initial technology development efforts focusing on human machine interfaces, the squad common operating picture in three dimensions, and the synchronization of kinetic and non-kinetic engagement capabilities.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Complete initial squad-system development efforts focusing on an automatic, augmenting system to increase squad performance and the integration of previously developed technology to enhance dismounted operations. - Conduct system-level experimentation and evaluation in relevant conditions with operational units with increased number of humans and unmanned systems in the squad. - Initiate expanded squad-system development efforts with focus on multiple squads and threat capabilities analogous to near-peer/peer states. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects completion of initial technology efforts and focus on system-level experimentation.			
Title: Mobile Force Protection (MFP)	16.156	33.000	37.000
Description: The goal of the Mobile Force Protection (MFP) program is to develop and demonstrate an integrated system capable of defeating a raid of self-guided small unmanned aircraft (sUAS) attacking a high value convoy on the move. By focusing on protecting mobile assets, the program will emphasize low footprint solutions, in terms of size, weight, power (SWaP), and manning, which will benefit other counter UAS missions and result in more affordable systems. Defending in a variety of operating environments against these sUAS threats and associated concept of operations requires several breakthroughs in affordable technology to sense, decide and act on a compressed timeline while mitigating collateral damage. The program seeks to develop solutions applicable to the defense of mobile ground and naval forces that can also potentially defeat more conventional threats. The solution will be scalable and modular such that it can be deployed in multiple defense applications and does not become obsolete with evolving threat capability. ***FY 2018 Plans:*** - Conduct affordability and cost analysis. - Complete system conceptual designs. - Integrate early system implementation able to protect a fixed site from a small raid of multiple Radio Controlled UASs via non-kinetic and kinetic neutralization techniques. - Conduct an open air demonstration that will include realistic threats, performance models, signatures, networks, and environmental factors. - Perform modeling, simulation, and lab demonstrations to evaluate advanced algorithms and sub-systems for integration. - Modify the end-to-end system to integrate into representative tactical vehicles for relocation by reducing size, weight and power. - Continue to develop sub-systems that will be able to operate while on the move. - Develop new interfaces and integrate novel algorithms in an open architecture system to reduce manning, false alarm rate, and reaction time.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Update affordability and cost analysis. ***FY 2019 Plans:*** - Conduct two open air demonstrations that will include advanced airborne threats and complex environmental factors. - Perform advanced modeling and simulation to validate system performance in operational environment. - Modify the end-to-end system to enable operations while on the move by reducing size, weight and power. - Finalize development of sub-systems that will be able to operate while on the move. - Validate graphic user interface that reduces manning false alarm rate, and reaction time. - Final update to affordability and cost analysis. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects completion of detailed design and initiation of end-to-end system development and testing.			
Title: Precision Kinetic Light Strike* ***Description:*** *Formerly Precision Light Strike Munition (PLSM) The Precision Kinetic Light Strike program will seek to develop a small, lightweight, guided kinetic weapon for lightweight maneuver forces. Current short-range weapons are used against a variety of target sets using different munitions without the benefit of active guidance. Current long-range weapons are highly effective against a specific target set at range, but are too large or heavy to employ in needed numbers, have a high cost per shot/procurement cost, and often require burdensome logistics or dedicated specialized systems to use. The program goal is to improve on the existing, lightweight unguided munition systems by increasing range, accuracy, and lethality, while reducing cost. These improvements will leverage advances in miniaturization, precision guidance and warheads. Precision Kinetic Light Strike seeks also to take advantage of commercial technologies whenever possible to provide a low-cost, multi-use, and multi-function precision engagement capability. The Precision Kinetic Light Strike program could significantly increase the combat power of small units with reduced burden, while significantly reducing cost relative to near-peer and peer adversaries. ***FY 2018 Plans:*** - Model system performance against multiple target sets. - Complete trade studies, evaluate concepts and performance metrics, and complete simulations for the most promising concept(s). - Initiate development efforts for high-risk and high-impact component technologies. - Initiate system-level design and development efforts. ***FY 2019 Plans:*** - Continue development efforts for high-risk and high-impact component technologies.	-	5.000	16.000

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Update models and simulations of selected designs. - Continue system-level design and complete preliminary prototype design(s). - Continue system-level development efforts with focus on the subsystems with the highest risk. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects transition from initial modeling and studies to specific technology development and prototype design.			
Title: PDUE: Autonomous Building Search Persistent Deterrence in Urban Environments* ***Description:*** *Formerly part of Urban Operations The goal of the PDUE: Autonomous Building Search Persistent Deterrence in Urban Environments program is to generate capabilities which would allow distributed forces to operate effectively in dense urban areas (e.g. megacities). Military operations in dense urban environments require massive investments in materiel and manpower to clear and hold terrain. Past urban operations indicate the pressing need to maintain security of cleared areas to prevent the enemy from reoccupying or moving freely through these areas. This program seeks to allow the ability to gain, hold, and control areas of the dense urban combat zone over extended periods without the physical presence of warfighters. Just as police units perform presence patrols in neighborhoods to create a pervasive presence that ultimately deters crime within an area, this program seeks to create a system of autonomous ground and air platforms that monitor an area overtly to deter enemy operations in a designated area. Extending this analogy, police and military follow strict rules of engagement that prescribe an escalation of force appropriate with the level of hostilities and confidence that an individual is engaged in nefarious behavior; this program will demonstrate the capability to escalate in force to allow future operations in the presence of civilians as well as the enemy. This mission will require the integration and maturation of novel sensors, urban air vehicles with lethal and non-lethal capabilities, and potentially ground platforms capable of navigating and maneuvering through urban environments. Enabling capabilities would focus on enhanced tactical situational awareness, precise control of destructive and non-destructive effects, cyber- and electronic warfare robustness, and predictive capabilities to analyze avenues of approach and freedom of movement. ***FY 2018 Plans:*** - Identify critical operational needs, tactical and environmental issues and key measures of effectiveness. - Conduct trade space analysis regarding sensing range, battery life, and optimal placement as well as aerial vehicle mobility and develop overall system architecture. - Develop adversarial path planning and asset allocation models that select routes to fly and locations to observe based on likely enemy actions. ***FY 2019 Plans:***	-	5.000	15.000

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Conduct initial development of sensing and tracking capabilities integrated into an aerial platform. - Conduct initial development of lethal and non-lethal capabilities integrated into an aerial platform. - Perform initial evaluation of aerial vehicle flights coupled with sensor emplacement. - Demonstrate path planning and sensing focused on deterring enemy actions. - Continue development of lethal and non-lethal capabilities integrated into an aerial platform. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects transition from initial studies and modeling to iterative testing and algorithm enhancement.			
Title: Subterranean (SubT) Challenge*	-	5.000	16.000
Description: *Formerly part of Urban Operations The DARPA Subterranean (SubT) Challenge will develop novel integrated solutions capable of mapping and navigating complex and dynamic terrains (tunnel systems, urban underground and cave networks); sensors and computation for perception in austere conditions; distributed information sharing in degraded communications environments; and collaborative autonomy enabling extended operations with minimal human interventions. The core objective of the SubT Challenge is to find the solution(s) which best outperforms current approaches for manually and laboriously mapping and searching subterranean environments. Newly developed capabilities will span across four technology focus areas in autonomy, perception, networking, and mobility technologies. The program will increase the diversity, versatility, and robustness of relevant system technologies, capable of addressing the multi-faceted needs of a wide range of environments. Innovations will be explored in the context of a public-facing, broadly inclusive DARPA Challenge. ***FY 2018 Plans:*** - Initiate system and virtual development approaches. - Release rules and structure of the challenge. - Initiate virtual test bed infrastructure. ***FY 2019 Plans:*** - Conduct baseline design, development, integration, of proposed solutions in the sub-domain of tunnel systems. - Conduct circuit competition in the sub-domain of tunnel systems. - Assess technology maturity and predicted technology trends to identify research and development needs and gaps. - Continue development and refinement of the virtual test bed. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 increase reflects transition from initial development to circuit competitions and virtual test bed refinement.			
Title: Operational Fires ***Description:*** The goal of the Operational Fires (OpFires) program is to develop and demonstrate a novel ground-launched system enabling hypersonic boost glide weapons to penetrate modern enemy air defenses and rapidly and precisely engage critical time sensitive targets. This program seeks to develop an advanced booster capable of delivering a variety of payloads at a variety of ranges. Additional considerations include the need for compatible mobile ground launch platforms enabling integration with existing ground forces and infrastructure, and specific system attributes required for rapid deployment and redeployment. The OpFires program will conduct a series of subsystem tests designed to evaluate component design and system compatibility, and culminate in integrated end-to-end flight tests. OpFires will leverage and integrate ongoing investments in hypersonic tactical boost glide vehicles (e.g., DARPA's Tactical Boost Glide (TBG) program) to achieve these objectives. ***FY 2018 Plans:*** - Conduct independent assessment of configurations using Government Reference Vehicle (GRV) baseline. - Develop conceptual launcher designs compatible with existing ground forces and infrastructure. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects transfer to PE 0603286E, Project AIR-01.	-	6.000	-
Title: Mobile Infantry (MI) ***Description:*** The Mobile Infantry (MI) program will explore the development of a system-based, mixed team of mounted/ dismounted warfighters, and semi-autonomous variants of platforms. The MI system concept will allow for a combined set of mounted and dismounted operations and for a larger area of operations over more aggressive timelines than standard infantry units. To improve operational effectiveness of the warfighter teams when dismounted, the semi-autonomous platforms, when unmanned, act as multipliers to the squad, such as extended and mobile fire support platforms and allow the MI mixed teams to perform higher risk exposure and access missions. ***FY 2018 Plans:*** - Complete technology development efforts. - Evaluate integrated technologies in relevant environments with single vehicle and section-level experiments. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	5.000	2.000	-
Title: Ground Experimental Vehicle (GXV)	9.600	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The goal of the Ground Experimental Vehicle (GXV) program was to investigate ground vehicle technologies that enable crew/vehicle survivability through means other than traditional heavy passive armor solutions. The focus of the GXV program was technology development across multiple areas to simultaneously improve military ground vehicle survivability and mobility. Coupled with the development of technologies, the GXV program defined concept vehicles to showcase these developmental technologies. Technology development areas included increasing vehicle tactical mobility, survivability through agility, and crew augmentation.			
Accomplishments/Planned Programs Subtotals	61.166	92.675	112.503

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-06 / *ADVANCED TACTICAL TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
TT-06: *ADVANCED TACTICAL TECHNOLOGY*	-	7.269	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Advanced Tactical Technology project focused on broad technology areas including compact, efficient, frequency-agile, diode-pumped, solid-state lasers for a variety of applications including infrared countermeasures, laser radar, holographic laser sensors, chemical sensing, communications, and high-power laser applications.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Laser Ultraviolet Sources for Tactical Efficient Raman (LUSTER)	7.269	-	-
Description: The Laser Ultraviolet Sources for Tactical Efficient Raman (LUSTER) program developed a compact laser suitable for a wide array of DoD applications, such as sensing the presence of chemical agents. The program developed a semiconductor laser that emits deep ultraviolet (UV) radiation with high efficiency, high laser purity, and an output power over one watt. This represents a significant advance over the state of the art, since existing deep UV lasers are bulky, highly inefficient, and expensive. Semiconductor lasers, on the other hand, benefit from low-costs, established manufacturing processes, compact size, and unique electro-optical performance capabilities.			
Accomplishments/Planned Programs Subtotals	7.269	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
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COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
TT-07: *AERONAUTICS TECHNOLOGY*	-	70.367	67.378	59.119	-	59.119	57.678	60.328	62.528	52.528	-	-

A. Mission Description and Budget Item Justification

Aeronautics Technology efforts will address high payoff opportunities that dramatically reduce costs associated with advanced aeronautical and aerospace systems and/or provide revolutionary new system capabilities for satisfying current and projected military mission requirements. This includes advanced technology studies of revolutionary propulsion, vehicle, and launch concepts, sophisticated fabrication methods, and examination of novel materials and enabling technologies for aeronautic and aerospace system applications.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Aircrew Labor In-cockpit Automation System (ALIAS)	23.867	19.378	11.000

Description: The Aircrew Labor In-cockpit Automation System (ALIAS) program will design, develop, and demonstrate a kit enabling affordable, rapid automation of selected aircrew functions across a broad range of aircraft. ALIAS intends to enable reduction of aircrew workload and/or the number of on-board aircrew to improve performance. The program will develop hardware and software to automate select aircrew functions and will employ novel, low impact approaches to interface with existing aircraft monitoring and control systems. The program will also develop tractable approaches to rapidly capture crew-station specific skills and aircraft unique behaviors. To accomplish this, ALIAS will leverage recent advances in perception, manipulation, machine learning, reusable software architectures, autonomous systems architecture, and verification and validation. ALIAS will culminate in a demonstration of the ability to rapidly adapt a single system to multiple aircraft and execute simple missions. This reliability enhancement capability will enable new operational concepts for reuse of existing air assets and allow a reduction in the number of aircrew required.

FY 2018 Plans:
- Demonstrate knowledge acquisition timeline and kit installation/removal on other aircraft.
- Refine system human interface.
- Conduct integrated system flight demonstration on an operational aircraft to include contingency management.
- Continue system refinement and demonstration on multiple aircraft.
- Initiate the transition of select knowledge acquisition, perception, and interface technologies to operational aircraft.

FY 2019 Plans:
- Conduct integrated system flight demonstration on operationally representative aircraft with reduced crew operations.
- Proceed with system installation and integration on a commercial aircraft with enhanced capabilities.
- Continue civil certification process of a commercial aircraft to support flight demonstrations that provide input for reduced crew operations.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Refine human machine interface to support multiple operational mission scenarios. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects transition to final flight demonstrations.			
Title: Gremlins ***Description:*** The goal of the Gremlins program is to develop platform technologies that enable a new class of distributed warfare. The Gremlins concept envisions small air-launched unmanned systems that can be responsively dispatched in volley quantity from commodity platforms, fly into contested airspace, conduct a moderate duration mission, and ultimately be recovered. Key enabling technologies for the concept include smaller developmental payloads that benefit from multiple collaborating host platforms. The Gremlins program will conduct risk reduction and development of the host platform launch and recovery capability and develop and demonstrate a recoverable Unmanned Air Vehicle (UAV) platform concept. Enabling platform technologies will include precision relative navigation, advanced computational modeling, variable geometry stores, compact propulsion systems, and high speed digital flight control. The program will leverage these technologies, perform analytic trade studies, conduct incremental development, and ultimately demonstrate the potential for an integrated air-launched Gremlins unmanned platform. ***FY 2018 Plans:*** - Conduct demonstration system Preliminary Design Review. - Initiate detailed design of integrated demonstration system. - Fabricate and ground test demonstration system or subsystem mock-ups. - Perform wind tunnel or preliminary flight test of demonstration system components. - Conduct demonstration system Critical Design Review. ***FY 2019 Plans:*** - Conduct flight validation for launch and recovery capability. - Fabricate and ground test flight-worthy assets. - Conduct flight test demonstrating Gremlins mission objectives. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects transition of program from design, fabrication, and ground testing of subsystems and components to flight testing of the integrated system.	42.500	36.000	31.119
Title: Advanced Aeronautics Technologies ***Description:*** The Advanced Aeronautics Technologies program will examine and evaluate aeronautical technologies and concepts through applied research. These may include the feasibility studies of novel or emergent materials, devices and tactics for both fixed and rotary wing air vehicle applications, as well as manufacturing and implementation approaches. The areas of	4.000	2.000	2.000

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-07 / *AERONAUTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
interest range from propulsion to control techniques to solutions for aeronautic mission requirements. The result of these studies may lead to the design, development, and improvement of prototypes. ***FY 2018 Plans:*** - Research enabling technology and sub-system feasibility experiments to support novel aeronautic concepts. - Conduct trade studies of candidate technologies. ***FY 2019 Plans:*** - Perform studies to support development of innovative prototypes. - Initiate new studies of novel technologies to improve speed and range. - Conduct trade studies of candidate technologies.			
Title: OFFensive Swarm-Enabled Tactics (OFFSET)	-	10.000	15.000
Description: The OFFSET program will design, develop, and demonstrate a swarm system architecture to advance the innovation, interaction, and integration of novel swarm tactics. The program will examine enabling technologies for collaborative autonomy for large teams of unmanned systems, including unmanned ground and air capabilities through the use of both virtual, game-based and physical, live-fly testbeds. Key research thrusts include the development of advanced swarm tactics-centered autonomy and development of human-swarm teaming interface technologies. These combined enhancements will facilitate insights and enable employment of these collective systems to address current needs and defeat future threats. The program will consider technologies supporting U.S. ground and air operations, extensible to other operating environments, requiring organic and/or tactical swarm capabilities, leveraging low-cost, rapidly deploy-able, autonomous system technologies. ***FY 2018 Plans:*** - Assess technology maturity and anticipate technology trends to identify research and development needs and gaps. - Identify key technology advances required for swarm tactics concepts of deployment and employment. - Initiate research and development for integration of advanced sensors, mobility, communication, and command & control technologies. - Conduct capability-based field experimentation events that demonstrate swarm tactics for scaled missions of relevance to urban combat operations. - Initiate Swarm Sprints for specific technology thrust areas relevant to swarm tactics and swarm autonomy. ***FY 2019 Plans:*** - Conduct additional capability-based field experimentation events that demonstrate swarm tactics for scaled missions of relevance to urban combat operations. - Assess technology maturity and anticipate technology trends to identify research and development needs and gaps.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-07 / *AERONAUTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Initiate Swarm Sprints for specific technology thrust areas relevant to human-swarm teaming. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects progress to increasingly difficult and complex scenarios.			
Accomplishments/Planned Programs Subtotals	70.367	67.378	59.119

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
TT-13: *INFORMATION ANALYTICS TECHNOLOGY*	-	114.414	150.179	116.283	-	116.283	110.925	118.954	127.114	160.114	-	-

A. Mission Description and Budget Item Justification

The Information Analytics Technology project develops technology for analyzing data and information arising from: 1) intelligence networks; 2) open and other external sources; 3) sensors and signal/image processors; and 4) collection platforms and weapon systems. Technical challenges include the need to process huge volumes of diverse, incomplete, and uncertain data in tactically-relevant timeframes. Efforts address problems related to causal modeling, automated model construction, media integrity, graph matching, biometrics-based health assessment, domain-specific search, enterprise network defense, social media analysis, and visualization. Operational benefits include deeper understanding of the evolving operational environment tailored to the needs of commanders at every echelon. Promising technologies are evaluated in the laboratory and demonstrated in the field to facilitate transition.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Causal Exploration of Complex Operational Environments	19.000	25.600	24.300

Description: The Causal Exploration of Complex Operational Environments program is developing advanced modeling, analysis, simulation, and visualization tools to enable command staffs to rapidly and effectively design, plan and manage missions in complex, hybrid operational environments. The U.S. military increasingly operates in remote and unstable parts of the world where mission success depends heavily on cooperation with a wide variety of stakeholder groups on civil, economic, and military matters. These groups typically include host nation government organizations, local civilian groups, and non-governmental organizations, each of which has priorities, sensitivities and concerns that may differ significantly. Current mission design and planning technologies do not adequately model the range of options or the inherent uncertainties. This program will develop tools to create causal, computational models that represent the most significant relationships, dynamics, interactions, and uncertainties of the operational environment including political, military, economic, and social factors. These tools will enable command staffs to design and quantitatively assess potential courses of action in complex operational environments.

FY 2018 Plans:

- Develop technologies for populating knowledge bases with extracted entities, events and relationships in selected operational environments.
- Develop information integration and scenario modeling frameworks and interfaces to support operational design and planning for complex hybrid warfare environments.
- Develop interfaces for rapidly visualizing and evaluating models and likely outcomes of alternative courses of action.
- Implement, execute, and assess models that support the design of representative hybrid missions.

FY 2019 Plans:

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Produce an initial prototype system and collaborate with operational and transition partners to assess models for selected complex operational environments. - Develop and demonstrate techniques to quantify uncertainty in inputs and models. - Expand visualizations and user interfaces to support exploration and refinement of models. - Refine methodologies and measurements to address dynamically changing models and enable component comparisons. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects minor program repricing.			
Title: Data-Driven Discovery of Models (D3M)	19.816	26.840	22.500
Description: The Data-Driven Discovery of Models (D3M) program is developing automated model discovery techniques and tools that enable non-expert users to create empirical models of real, complex processes and phenomena. The ability to understand the battlespace is driven increasingly by analysis of sensor and open source data. The DoD and the Intelligence Community (IC) are fundamentally limited by a shortage of expert data scientists to construct empirical models that predict behaviors and anticipate contingencies during tactical and strategic planning. D3M will address this need by creating technologies that automate the construction of complex empirical models. D3M technologies will include a library of data modeling primitives that are automatically selectable; automated approaches for composition of complex models from modeling primitives; and intuitive mechanisms for human-model interaction that enable curation of models by non-experts. D3M technical development will focus on the types of empirical modeling problems commonly encountered by the DoD and IC. ***FY 2018 Plans:*** - Develop a library of modeling primitives that transform, structure, reduce, infer, and augment data, and a capability to compose modeling primitives into complex models. - Expand the collection of data science and empirical science problems to enable automated learning of analytic approaches. - Initiate development of an end-to-end, integrated system to automatically generate and propose models that are relevant to a given problem. - Address problems of overfitting, spurious correlation, and biased training data by creating curation aids that explain model limitations and data dependencies to non-expert users. ***FY 2019 Plans:*** - Enhance modeling primitives and incorporate into the integrated toolkits. - Develop and synthesize multi-modal predictive models for unsolved problems, including automated data collection for data augmentation. - Develop question formalization frameworks and specifications for question decomposition to support user-model interaction.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate automated composition of complex models in coordination with operators from multiple domains. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is the result of development work ramping down and the focus shifting to demonstrations in coordination with operators from multiple domains.			
Title: Distributed Battle Management (DBM) ***Description:*** The Distributed Battle Management (DBM) program will develop mission-driven architectures, protocols, and algorithms for battle management (BM) in contested environments. The military is turning to networked weapons and sensors on-board a heterogeneous mix of multi-purpose manned and unmanned systems. In contested environments, it is a challenge for BM networks to communicate with subordinate platforms due to extensive adversarial cyber and electronic warfare operations, anti-satellite attacks, and the need for emissions control in the face of a formidable integrated air defense system. The Distributed Battle Management program will seek to develop a distributed command architecture with decentralized control of mission-focused asset teams. The architecture will enable rapid reaction to ephemeral engagement opportunities and maintain a reliable BM structure, despite limited communications and platform attrition in continuously evolving threat environments. The program will incorporate highly automated decision making capability while maintaining vital human-on-the-loop operator approval. ***FY 2018 Plans:*** - Conduct software flexibility tests to demonstrate the ability to insert software upgrades without disrupting the BM structure. - Conduct a virtual, constructive-based simulation of the air portion of an Air-to-Ground battle using DBM software components. - Use DBM components in a simulation event for the System of Systems Integration Technology and Experimentation (SoSite) program (budgeted in PE 0603766E, Project NET-01). - Conduct a live-fly experiment with a virtual, constructive-based simulation of the air portion of an Air-to-Ground battle using DBM software components. - Use DBM components in a live-fly event for the SoSite program. ***FY 2019 Plans:*** - Use DBM components in a live-fly experiment in support of transition to the services (Navy or Air Force). - Expand the number of flight systems modeled in DBM system. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects a reduction in algorithm development, implementation, and integration emphasis, with focus shifting to experiments and demonstration.	10.726	21.250	6.000
Title: Media Forensics (MediFor)	19.079	28.879	23.000

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Media Forensics (MediFor) program is creating technologies for analyzing media content to determine trustworthiness for military and intelligence purposes. Current approaches to media forensics are labor intensive, requiring analysts and investigators to undertake painstaking analyses to establish context and provenance. The program will develop, integrate, and extend image and video analytics to provide forensic information that can be used by analysts and automated systems to quickly determine the integrity of open source and captured images and video. Technologies will transition to operational commands and the intelligence community. ***FY 2018 Plans:*** - Extend approaches to counter evolving media-editing technologies to detect indicators obscured by noise and compression, and to address synthetic media created using generative adversarial techniques. - Develop methods to fuse knowledge from multiple forensic engines to determine whether a manipulation renders media unsuitable for an intended application. - Develop a large-scale, integrated integrity-assessment platform with graphical user interfaces for operator interaction. - Evaluate the integrity-assessment platform on realistic research data. ***FY 2019 Plans:*** - Develop quantitative measures of integrity relevant to diverse needs of government users and specific missions. - Enhance the effectiveness of algorithms that must operate against media manipulated at large scales. - Develop association methods to track and assess related media assets that are subject to coordinated manipulation by adversaries. - Evaluate the effectiveness of the integrated integrity-assessment platform on relevant operational data. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is the result of development work ramping down and the focus shifting to testing media integrity-assessment techniques to establish utility for transition partners.			
Title: Modeling Adversarial Activity (MAA)	9.000	16.400	21.500
Description: The Modeling Adversarial Activity (MAA) program is developing technologies for generating high-confidence indications and warnings for weapons of mass terror (WMT) activities. WMT pathways consist of networks or links among individuals, groups, organizations, and other entities that act to promote or enable the development, procurement, possession, transportation, or proliferation of WMTs and related capabilities. Monitoring and controlling WMT pathways is essential to denying access to WMT technology, knowledge, materials, expertise, and weapons. MAA will create graph models reflecting prototypical WMT pathways, develop methods for creating merged activity graphs by aligning entities across multiple intelligence modalities, develop algorithms to match empirical activity graphs with pathway models, and create synthetic data sets at scale to support			

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
development and testing of WMT activity detection techniques. MAA research will be coordinated with the Defense Threat Reduction Agency (DTRA) and the Department of Homeland Security (DHS). ***FY 2018 Plans:*** - Formulate graph models for pathway activity sequences designed by WMT subject matter experts. - Design computationally feasible approaches for aligning entities across multiple intelligence modalities and for approximate graph matching. - Initiate implementation of graph models and graph matching algorithms. - Collaborate with DTRA and DHS on methods for generating synthetic activity data with realism adequate for testing WMT pathway recognition techniques. ***FY 2019 Plans:*** - Implement graph alignment techniques, and assess strengths and weaknesses of alternative approaches on synthetic data. - Implement techniques for approximate matching of activity graphs, and demonstrate pathway detection on synthetic data. - Create an initial prototype pathway recognizer, and demonstrate the capability to detect modeled WMT activity sequences in synthetic data. - Collaborate with DTRA and DHS to implement techniques in their environments and to optimize techniques for efficient and timely execution on their computational infrastructure. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued development of techniques and software for WMT pathway discovery and additional work to integrate these into a prototype pathway recognition system.			
Title: Warfighter Analytics using Smartphones for Health (WASH)	-	15.000	18.983
Description: The Warfighter Analytics using Smartphones for Health (WASH) program is developing analytic techniques for continuous and real-time assessment of warfighter physiological health and cognitive state based on the multiple sensor data streams generated by modern smartphones. Recent research in the area of smartphone biometrics has shown the feasibility of measuring user physiological and behavioral parameters for purposes of user authentication. WASH will extend these smartphone biometrics to reliably measure additional user physiological and behavioral parameters relevant to health assessment and the diagnosis of disease. If successful, WASH will produce a mobile application that continuously and reliably assesses warfighter health and combat/mission readiness. WASH is coordinated with the Naval Health Research Center. ***FY 2018 Plans:*** - Develop a privacy framework and privacy processes appropriate for smartphone-based physiological health and cognitive state assessment.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop data analytics for extracting context from smartphone sensor data. - Identify promising digital biomarkers for physiological conditions and cognitive state. ***FY 2019 Plans:*** - Develop secure, privacy-preserving, cloud-based data ingest and storage technologies for collecting, organizing, and associating user smartphone, physiological health, and behavioral data. - Develop a mobile application to capture user smartphone data passively and securely, and to compute digital biomarkers. - Perform assessments of sensitivity and specificity of smartphone-based digital biomarkers for detection and diagnosis of physiological disease and assessment of cognitive state. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects continued work to develop techniques to capture user smartphone data and to assess user physiological health and cognitive state and additional work to assess performance of techniques.			
Title: Memex ***Description:*** The Memex program is developing search technologies to revolutionize the discovery, organization, and presentation of domain-specific content. Current search technologies have limitations in search query format, retrieved content organization, and infrastructure support. These current technologies impose an iterative search process that is time-consuming and inefficient, typically producing only a fraction of the available information. Memex is creating a new domain-specific search paradigm to discover relevant content and organize it in ways that are more immediately useful to specific missions and tasks. In addition, Memex domain-specific search engines will extend the reach of current search capabilities to the deep web and non-traditional content. Memex technologies will enable the military, government, and commercial enterprises to find and organize mission-critical information on the Internet and in large intelligence repositories. Anticipated mission areas include counter-terrorism, counter-drug, anti-money-laundering, and anti-human-trafficking, with transition partners from DoD and other U.S. Government activities. ***FY 2018 Plans:*** - Develop optimized components and integrated applications that address new domain specific search requirements arising from the national security and intelligence communities. - Transition software components and integrated systems for multiple national security and intelligence missions. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	15.608	9.460	-
Title: Network Defense	9.625	6.750	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Network Defense program is developing technologies to detect network attacks. U.S. computer networks are continually under attack, and these attacks are typically handled by individual organizations as they occur. Analyzing network summary data across a wide array of networks will make it possible to identify trends and patterns visible only when the data is viewed as a whole. Network Defense is developing novel algorithms and analysis tools that enable a big picture approach for identifying illicit behavior in networks. This analysis and subsequent feedback to system administrators, security engineers, and decision makers will enhance information security in both the government and commercial sectors. ***FY 2018 Plans:*** - Develop distributed versions of the most effective algorithms to permit deployment on a decentralized global infrastructure. - Extend comprehensive test and evaluation of the most promising techniques to adversarial use cases. - Transition resulting capabilities to U.S. government agencies, defense industrial base organizations, and other U.S. commercial companies. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Quantitative Crisis Response (QCR) ***Description:*** The Quantitative Crisis Response (QCR) program developed digital tools that help operational partners better understand how information is being used by adversaries, and predict and assess the effects of adversary information campaigns and of countermeasures quantitatively, in real time, and at scale. The tools enable operators to assess population-scale radicalization and other potential effects of the information being traded through social media and other communications channels. QCR is coordinated with multiple national security agencies, Combatant Commands, and the Department of State.	7.000	-	-
Title: XDATA ***Description:*** The XDATA program developed computational techniques and software tools for analyzing large volumes of data, both semi-structured (e.g., tabular, relational, categorical, metadata, spreadsheets) and unstructured (e.g., text documents, message traffic). Central challenges addressed included; a) development of scalable algorithms for processing imperfect data in distributed data stores; and b) creation of effective human-computer interaction tools for facilitating rapidly customizable visual reasoning for diverse missions. The program developed open source software toolkits that enable flexible software development to support users processing large volumes of data in timelines commensurate with mission workflows of targeted defense applications. An XDATA framework supports minimization of design-to-deployment time of new analytic and visualization technologies on diverse distributed computing platforms, and accommodates changing problem spaces and collaborative environments.	4.560	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Accomplishments/Planned Programs Subtotals	114.414	150.179	116.283

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	208.855	224.440	226.898	-	226.898	224.572	249.278	241.391	244.914	-	-
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	114.655	112.050	108.766	-	108.766	111.608	130.928	130.928	141.029	-	-
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	94.200	112.390	118.132	-	118.132	112.964	118.350	110.463	103.885	-	-

A. Mission Description and Budget Item Justification

The Materials and Biological Technology Program Element is budgeted in the Applied Research Budget Activity because its objective is to develop material, biological and energy technologies that make possible a wide range of new military capabilities.

The major goal of the Materials Processing Technology project is to develop novel materials, fabrication and processing techniques, models, devices and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of technology areas including manufacturing, electronics, sensors, optics, and complex and autonomous systems.

The Biologically Based Materials and Devices project acknowledges the growing and pervasive influence of the biological sciences on the development of new DoD capabilities. This influence extends throughout the development of new materials, devices, and processes and relies on the integration of biological breakthroughs with those in engineering and the physical sciences. Contained in this project are thrusts that apply biology's unique fabrication and manufacturing capabilities to produce novel chemicals and materials at scale, as well as research to develop new high-throughput methods and devices to analyze biological changes at the cellular and molecular level. Additional work leverages advances in synthetic biology to engineer novel biological systems and develop new approaches to biosecurity. This project also includes major efforts aimed at integrating biological, computational, and digital sensing methodologies to explore neuroscience technology and maintain human combat performance.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	220.456	224.440	232.700	-	232.700
Current President's Budget	208.855	224.440	226.898	-	226.898
Total Adjustments	-11.601	0.000	-5.802	-	-5.802
• Congressional General Reductions	-3.000	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	-4.000	0.000			
• SBIR/STTR Transfer	-4.601	0.000			
• TotalOtherAdjustments	-	-	-5.802	-	-5.802

Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction, reprogrammings and the SBIR/STTR transfer.

FY 2018: N/A

FY 2019: Decrease reflects completion of the BioDesign and Biological Robustness in Complex Settings programs in FY 2018.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	Project (Number/Name) MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	114.655	112.050	108.766	-	108.766	111.608	130.928	130.928	141.029	-	-

A. Mission Description and Budget Item Justification

The major goal of the Materials Processing Technology project is to develop novel materials, fabrication and processing techniques, models, devices and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of technology areas including manufacturing, electronics, sensors, optics, and complex and autonomous systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Materials Processing and Manufacturing	25.098	17.216	12.800

Description: The Materials Processing and Manufacturing thrust is exploring new manufacturing and processing approaches that will dramatically lower the cost and decrease the time required to fabricate DoD parts and systems. It will also develop approaches that yield new materials, materials capabilities and parts that cannot be made through conventional processing approaches, as well as address efficient, low-volume manufacturing. As a result of recent advances in manufacturing techniques such as 3D printing and manufacture on demand, and the push towards programmable hardware in embedded systems, the development cycle from design to production of both hardware and software is severely bottlenecked at the design phase. Integration of advanced materials with superior properties into manufacturing approaches is also complex and slow, hampering new materials integration and evolution of design. Research within this thrust will create methods to translate natural inputs into software code and mechanical design, as well as reduce manufacturing complexity through new material feedstock formats with reconfigurable processing technologies.

FY 2018 Plans:

- Demonstrate capability to fabricate metallic hardware using direct metal laser sintering (DMLS) displaying defect distribution similar to prediction of process simulation hardware.
- Demonstrate ability of process-microstructure-tensile models to define optimized probabilistic process window for electron beam additive manufacturing (EBAM) to ensure fabricated material meets minimum properties.
- Account for effects of scale in composite bond process model by building larger component box test articles.
- Develop and demonstrate integrated hierarchical framework of empirical, process, and physics models that predicts cumulative density functions for component quantities of interest.
- Demonstrate a reconfigurable forming method at production rate for short element reinforced matrix compounds that meets or exceeds current DoD performance.

FY 2019 Plans:

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate pilot-scale production of tailorable, high-performance carbon fiber-based feedstock that meets or exceeds state-of-the-art aerospace materials capability. - Demonstrate that a multifunctional element can be incorporated into the feedstock while maintaining performance. - Demonstrate that a multifunctional component can be formed without degradation of performance in either the structural or the functional component. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease is due to refocus of efforts outside of manufacturing.			
Title: Chemical Processing for Force Protection	26.654	20.434	19.452
Description: Research in this thrust is focused on the development of new chemical approaches and technologies across a broad spectrum of DoD needs. One area involves development of innovative approaches for scalable small molecule synthesis coupled with predictive tools for route design, possibly offering a new strategy to discover how to make new molecules such as pharmaceuticals and explosives. Another focus combines existing strategies for destruction of chemical agents with development of new processing methods to provide a remediation system that can process any chemical agent at the site of storage. In addition, investments in this thrust will advance chemical characterization, information management and analysis, and automation. ***FY 2018 Plans:*** - Increase chemical remediation/conversion of DoD-relevant model compounds to 99.999%. - Integrate inline monitoring with remediation/conversion system to yield initial prototype. - Demonstrate the automated route design and continuous flow synthesis of a structurally complex active pharmaceutical ingredient (API) such as naproxen or pregabalin. - Integrate the automated route design with the continuous flow system to yield a fully automated synthesis of three DARPA-defined challenge molecules. ***FY 2019 Plans:*** - Demonstrate continuous flow synthesis of a molecule requiring a convergent approach (e.g., synthesis and subsequent combination of two intermediates). - Scale fully automated synthesis of one molecule and demonstrate capability for 1 metric ton/year equivalent with three days of continuous operation. - Develop a computational map of synthetic capabilities for existing modules that outlines the potential suite of molecules that can be generated in the automated device. - Demonstrate rapid search of reaction conditions (1,000s of reactions per hour) and initiate integration of these data into route design algorithms. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 decrease reflects minor program repricing.			
Title: Functional Materials and Devices	29.597	25.320	21.845
Description: The Functional Materials and Devices thrust is developing advanced materials, components and systems to improve device performance for DoD sensing, imaging and communication applications. One focus of this thrust involves development of advanced transductional materials that convert one form of energy to another for DoD-relevant applications in areas such as thermoelectrics. While promising transduction materials are known for a variety of applications, integration into devices has not been realized. Another focus area involves development of new multi-functional materials and device designs that will radically decrease the size, weight and power requirements of neutron sources for high-resolution neutron and x-ray imaging. Such devices should enable fieldable detection units for non-destructive evaluation of parts, detection of explosives and other DoD-relevant targets. ***FY 2018 Plans:*** - Demonstrate integrated transductional materials and device multi-physics models. - Perform final round of optimization of transductional materials and devices, and characterize their technical performance. - Provide updates to transductional models and deliver them in modeling software. - Integrate earlier developed materials/devices into a system proof of concept. - Refine final integrated compact neutron source prototypes. - Perform final integrated compact neutron source prototype testing. ***FY 2019 Plans:*** - Initiate research in high velocity energy transfer. - Initiate applications of novel quantum mechanical systems to computing. - Demonstrate new computational architectures based on new state-change and/or state-manipulation in materials. - Design and demonstrate metamaterial based sensors that have the ability to observe/detect through complex media. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects shift in focus to the Accelerating Discovery and Innovation thrust area.			
Title: Reconfigurable Systems	23.285	20.280	19.889
Description: In the Reconfigurable Systems thrust, new approaches are being developed to enable more rapid and robust adaptation of defense systems and systems-of-systems to changing mission requirements and unpredictable environments. This includes development of capabilities across sensing, perception, planning and control for autonomous, high-speed operation in cluttered environments without Global Positioning System (GPS) information. Additional work in this thrust focuses on how sensing systems and military systems-of-systems are designed for real-time resilient response to dynamic, unexpected signals			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
and contingencies. Research is developing a more unified view of system behavior that allows better understanding and exploitation of complex interactions among components, including development of formal mathematical approaches to complex adaptive system composition and design. These capabilities will impact autonomous systems and systems-of-systems, including those that involve humans, in a variety of DoD-relevant contexts. ***FY 2018 Plans:*** - Demonstrate high speed (>10 m/s) GPS-free flight in moderate clutter. - Demonstrate end-to-end mission capabilities including transition from outdoor to indoor flight. - Demonstrate integration of new mathematical and algorithmic methods into design framework. - Determine limitations of composable abstractions and formally define composability constraints. - Validate time-dynamic function model against war game data. - Initiate development of computationally tractable strategies for distributed, autonomous detection and tracking of chemical threats in urban environments. ***FY 2019 Plans:*** - Develop capability for self-diagnosis of current system performance from arbitrary set of sensors, behaviors, and constraints. - Demonstrate closed-loop single functional recomposition from a set of sub-system components. - Demonstrate redesign of system function to attrition and environmental change. - Develop generalizable strategies for sensor network designs that minimize complexity and maximize coverage. - Develop data collection and processing strategies that maximize signal-to-noise and enable determination of signal directionality with conventional sensors. - Integrate sensors in a network to determine and track signal location in complex (turbulent) airflow conditions. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects minor program repricing.			
Title: Accelerating Discovery and Innovation	10.021	28.800	34.780
Description: The Accelerating Discovery and Innovation thrust is developing new approaches, tools and technologies to speed the pace of scientific discoveries and technological innovations from idea generation and fundamental research through integration of technologies into fieldable products and systems in production. The path from idea generation to a discovery is a lengthy, complex process involving many unpredictable steps, cycles and stages across fundamental and applied research and development. Research in this thrust is focused on developing and implementing strategies to address many of the challenges and bottlenecks inherent along this path and to speed the rate at which an idea can be advanced into a concrete capability. Specific approaches include advanced multiplayer gaming technologies to catalyze development of new technology concepts, development of tools for data collection and visualization to accelerate fundamental and applied research, and strategies to			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
understand how seemingly benign commercially available technologies may be converted or combined into threats to military operations, equipment or personnel. ***FY 2018 Plans:*** - Develop high rate, integrated assembly processes that bridge the nanometer to centimeter length scales. - Investigate the applicability of feedstock assembly techniques for complex and heterogeneous systems. - Test methods for accelerating discoveries in the research community to demonstrate reduction in time for new idea generation and technology application. - Define integrated technology demonstrations to support scientific discovery and engineering innovation in areas of agency focus. ***FY 2019 Plans:*** - Investigate methods for the scale-up of nano- and micro-assembly techniques. - Test and evaluate retention of nanoscale properties when assembly process is scaled-up. - Develop software tools to facilitate an analytic multi-disciplinary conversation to facilitate the collective understanding and potential implications of emerging science and technology. - Develop software systems to aid in identifying emerging science and technology concepts and applications based on existing understanding. - Design and build a set of interoperable kits for military applications from easily obtainable components. - Design and build a highly capable reconnaissance-strike system that integrates the interoperable kits. - Test the reconnaissance-strike system(s) with military partners. - Investigate the understanding of what enables projected animations to be perceived as real. - Investigate new methods for studying human collectives. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects acceleration of technology advancements to support the warfighter and new investments in scientific discovery.			
Accomplishments/Planned Programs Subtotals	114.655	112.050	108.766

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	Project (Number/Name) MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	94.200	112.390	118.132	-	118.132	112.964	118.350	110.463	103.885	-	-

A. Mission Description and Budget Item Justification

The Biologically Based Materials and Devices project will leverage the growing and pervasive influence of the biological sciences for the development of new DoD capabilities. Contained in this project are thrusts that apply biology's unique fabrication and manufacturing capabilities to produce and detect novel DoD relevant chemicals, materials at scale, and devices for overmatch. Example projects include analyzing biological threats at the cellular and molecular level, mitigating the effect of threat agents on deployed warfighters, and developing remote, persistent sensor systems to detect terrestrial and maritime threats. This project also includes efforts to develop neuroscience technology for maintaining human combat performance.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Living Foundries	21.712	18.020	10.430

Description: The goal of the Living Foundries program is to create a revolutionary, biologically-based manufacturing platform for the DoD and the Nation. With its ability to perform complex chemistries, be flexibly programmed through DNA code, scale, adapt to changing environments, and self-repair, biology represents one of the most powerful manufacturing platforms known. Living Foundries seeks to develop the foundational technological infrastructure to transform biology into an engineering practice, speeding the biological design-build-test-learn cycle and expanding the complexity of systems that can be engineered. Ultimately, Living Foundries aims to provide game-changing manufacturing paradigms for the DoD, enabling adaptable, on-demand production of critical and high-value molecules.

Research thrusts will focus on the development and demonstration of open technology platforms to prove out capabilities for rapid (months vs. years) design and construction of new bio-production systems. The result will be an integrated, modular infrastructure across the areas of design, fabrication, debugging, analysis, optimization, and validation -- spanning the entire development life-cycle and enabling the ability to rapidly assess and improve designs. Key to success will be tight coupling of computational design, fabrication of systems, debugging using multiple characterization data types, analysis, and further development such that iterative design and experimentation will be accurate, efficient and controlled. Demonstration platforms will be challenged to build a variety of DoD-relevant, novel molecules with complex functionalities, such as synthesis of advanced, functional chemicals, materials precursors, and polymers (e.g., those tolerant of harsh environments). This program has basic research efforts funded in PE 0601101E, Project TRS-01.

FY 2018 Plans:

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate infrastructure pipelines capable of rapidly prototyping and generating DoD-relevant molecules in a semi-automated manner and initiate efforts to achieve full automation. - Test the ability to produce an additional set of ten molecules that are relevant to the DoD. - Demonstrate that the infrastructure pipeline is capable of rapidly prototyping strains that produce molecules. - Characterize impact of machine learning capabilities on design algorithms and identify increases in prototyping process efficiency. ***FY 2019 Plans:*** - Demonstrate a fully automated infrastructure pipeline capable of prototyping and generating DoD-relevant molecules. - Demonstrate ability to scale production of molecules to kilogram scale using biology. - Conduct pressure tests at the prototyping and design facility to evaluate the speed, breadth, and efficacy of the infrastructure designs. - Investigate methods to generate molecules that have not been previously synthesized using traditional chemistry. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects focused effort and limited infrastructure pipeline pressure testing.			
Title: Adaptive Immunomodulation-Based Therapeutics	24.460	16.962	16.006
Description: The Adaptive Immunomodulation-Based Therapeutics program will develop platform technologies to interrogate and define the biological pathways that will enhance operational readiness for DoD personnel. This program will aid the warfighter by improving immune response, minimizing inflammation, and restoring critical organ function post trauma. One approach to achieve this capability will require the development of new tools to stimulate and measure responses of the nervous system in order to harness the bioelectric code, enabling targeted therapy without the need for pharmacological products, ultimately reducing logistical requirements. An additional approach involves characterizing the host response in patients with severe infections, which provides a quantitative framework to guide therapy. Algorithms will be developed to evaluate and predict various physiological conditions for military personnel. Advances made under the Adaptive Immunomodulation-Based Therapeutics program will improve the response capabilities against severe biological threats and offer new avenues for treating disease or organ function to improve force readiness. ***FY 2018 Plans:*** - Refine anatomical maps and computational models of function for target neurophysiological circuits. - Quantify on-target responses to neurostimulation to validate computational models of feedback signals and therapeutic benefit. - Demonstrate the components comprising an integrated, closed-loop neuromodulation system to control health status in human or large animal studies.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Conduct in vivo safety and efficacy studies to evaluate long-term bio-interface functionality. ***FY 2019 Plans:*** - Quantify on-target responses to neurostimulation to validate feedback biomarkers, evaluate therapeutic benefit, and demonstrate circuit specificity. - Implement computational models of integrated neuromodulation and biomarker signaling for feedback control of health status. - Demonstrate sustained functionality of novel bio-interfaces for neuromodulatory control of health status in animal models. - Initiate clinical trials of closed-loop neuromodulation system. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects minor program repricing.			
Title: Enhancing Neuroplasticity	15.601	19.430	22.290
Description: The DoD needs tools to rapidly and effectively train military personnel in multifaceted and complex tasks. The Enhancing Neuroplasticity program will explore and develop stimulation methods and non-invasive devices to promote synaptic plasticity for improved learning paradigms. Key advances anticipated from this research will both create an anatomical and functional map of the underlying biological circuitry that mediates plasticity and optimize stimulation and training protocols to enable long-term retention for military personnel. Once successfully identified, the underlying mechanisms of targeted plasticity training can be applied to a broad range of cognitive skill training within the DoD, including foreign language learning, or data and intelligence analysis. ***FY 2018 Plans:*** - Demonstrate effects of training on neurons and neuronal network connectivity in task-specific areas of the brain. - Evaluate mechanistic components of targeted neuroplasticity training on brain neurophysiology and learning rate. - Investigate mechanisms for modulating neuroplasticity in humans with peripheral neurostimulation devices. - Test for off-target effects of peripheral neurostimulation and training. ***FY 2019 Plans:*** - Compare effects of various nerve stimulation targets on brain neurophysiology and learning rate. - Assess the combined impacts of neuromodulator receptor optimization with peripheral nerve stimulation to improve cognitive task performance. - Determine efficacy of various biomarkers to validate target nerve stimulation. - Initiate clinical studies of non-invasive nerve stimulation on learning. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 increase reflects transition of successful technologies to initial clinical studies.			
Title: Genome Protection Technologies* ***Description:*** *Formerly Biosecurity for Biotechnology The Genome Protection Technologies program will develop advances in critical efforts to generate a biodefense capability to control, counter, and reverse the effects of accidental or malicious misuse of gene editing technologies. This research will investigate new approaches for developing tunable controls to enable the safe and predictable use of synthetic genes and pathways. Additional work will develop protecting measures to prevent or limit unintended genome editing or engineering and develop new tools to recall or reverse engineered changes. Advances within this program will ensure that the U.S. remains at the vanguard of this now widespread, rapidly advancing field that poses potential national security threats due to the large-scale democratization of gene editing technologies. ***FY 2018 Plans:*** - Investigate novel small molecule and genetic countermeasures to prevent gene editing in cells. - Design and create engineered, reversible genetic elements for evaluation in a laboratory testbed. - Characterize the efficacy, stability, and fitness of engineered genetic constructs and countermeasures in a contained laboratory testbed. - Refine computational models to inform the design and function of engineered genetic controls and countermeasures and predict experimental outcomes. ***FY 2019 Plans:*** - Conduct laboratory animal model testing for safety and efficacy of small molecule and genetic countermeasures. - Use computational models to evaluate efficacy, stability, and fitness of gene editing controllers and countermeasures. - Demonstrate efficacy, stability, and fitness of gene editing controllers and countermeasures in laboratory animal models. - Characterize failure modes of gene editor controllers and countermeasures. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects transition from cells to animal model testing.	3.750	11.844	19.900
Title: Defend Against Crop System Attack* ***Description:*** *Formerly Accelerated Agricultural Engineering The Defend Against Crop System Attack program will develop a platform technology aimed at increasing the speed of DoD response to state or non-state actor release of biological threats directed at our crop systems. Conventional methods to defend	3.250	10.700	12.434

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
against these threats are generally slow and ineffective. This program will leverage recent advances in molecular and synthetic biology to enable rapid delivery of genes to plants for large-scale trait modification, improving resilience against adversary attack or emerging natural threats. Research within this program will develop an agnostic, scalable capability for protecting entire crop systems from emerging threats posed to food security by U.S. adversaries. ***FY 2018 Plans:*** - Develop a flexible plant transformation platform to genetically modify plants. - Demonstrate deployment of transgenes in contained greenhouse settings using environmental vectors that can be managed. - Integrate technologies developed for controlled deployment of genetic materials with the late-stage plant gene alteration methods. - Demonstrate the alteration of plant protein production through emerging gene editing technologies in a contained laboratory testbed. ***FY 2019 Plans:*** - Scale deployment of flexible plant transformation platforms in a controlled greenhouse setting. - Initiate integration of novel and existing failsafe capabilities for the trait delivery platform. - Investigate new approaches to increase the efficacy of genetic transmission. - Demonstrate predictable and repeatable transmission of genetic materials to plants. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects technology scale-up and transition to greenhouse testing.			
Title: Persistent Terrestrial Living Sensors* ***Description:*** *Formerly part of Accelerated Agricultural Engineering This program will develop engineered biological sensor platforms capable of detecting land-based threats (e.g., chemicals, radiation, explosives) and relaying unique signals to existing DoD ground, air, and space assets. Unlike conventional methods that passively monitor threats and are limited by sensor energy needs, these biological sensors are effectively energy independent, increasing the potential for wide distribution and environmental robustness. Resulting platforms developed within this program will enable a variety of remote, persistent monitoring and reporting capabilities to address threat scenarios relevant for national security, including detecting improvised explosive devices (IEDs) and protecting infrastructure. These sensors will provide a flexible suite to complement conventional sensor systems within the DoD. ***FY 2018 Plans:*** - Investigate novel approaches and genetic machinery designs for developing biology-based sensor systems.	-	3.000	9.012

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Identify and modify plant resource allocation strategies to accommodate plant sensing and reporting operations. ***FY 2019 Plans:*** - Develop a quantitative model to guide plant-based sensor resilience and environment flexibility. - Demonstrate the feasibility of combining high-specificity detection traits with physiological response traits by first exploring plant cell expression and quantitative modeling, and then by altering the physiology of plants. - Begin production of plants with individual sense and report traits. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects addition of modeling effort as well as preliminary technology testing and demonstration.			
Title: Transient CBRN Threat Defense*	-	8.510	16.060
Description: *Formerly Engineering Function The Transient CBRN Threat Defense program will create a transient, near immediate prophylaxis to protect military personnel against chemical, biological, radiological, and/or nuclear (CBRN) threats. Currently, military personnel rely on physical barrier technology (i.e., personal protective equipment) to mitigate the harmful effects of CBRN stressors. This program will include research to develop novel transient and reversible epigenetic therapies for prophylactic and therapeutic protections against a broad range of CBRN threats (e.g., nerve agents). In addition to overcoming constraints of traditional countermeasures to threat agents, successful work within this project will extend upon the DoD's limited protective capabilities (e.g., vaccines, anti-virals) to respond to re-emerging (e.g., Ebola, Zika), newly emerging, or engineered biothreats. ***FY 2018 Plans:*** - Generate foundational knowledge concerning cellular stress resistance against a broad range of CBRN threats. - Initiate investigation of novel delivery toolsets to facilitate CBRN stressor resistance in vivo. - Begin development of bioinformatics tools and validation methods that will improve the design and specificity of transient gene therapy strategies. - Explore scalable and adaptable platforms for a broad range of CBRN threats. ***FY 2019 Plans:*** - Determine feasibility for transient and reversible gene therapy for stress resistance. - Demonstrate genetic basis for cellular stress resistance in vivo. - Characterize effective delivery tools for gene therapy that enable stress resistance. - Characterize specificity of transient gene therapy in animal models. - Demonstrate effectiveness of stress resistance constructs to specific CBRN threats.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Initiate development of platform capabilities for scalable and adaptable CBRN threat response platform. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects preliminary technology testing and demonstration.			
Title: Persistent Aquatic Living Sensors ***Description:*** The Persistent Aquatic Living Sensors program will develop novel capabilities to sense and surveil submersibles (e.g., submarines, unmanned underwater vehicles) and divers in littoral waters using living organisms present in the environment. This effort will focus on characterizing marine biological behavior in response to targets of interest and developing the hardware, software, and algorithms that will translate organism behavior into DoD actionable information. By harnessing the unique capabilities of biology, including adaptation, response, and replication, work in this program will enable persistent surveillance in contested waters. Results from this research will enhance security for maritime activities and provide DoD naval operations with new sensing paradigms to complement current sensor technologies used in traditionally challenging regions across the world. ***FY 2019 Plans:*** - Investigate organism response to targets of interest in a laboratory environment using benchtop instrumentation. - Initiate research to convert organism response into robust sensing system by developing algorithms to classify organism response in relation to targets. - Research new reporting schemes to communicate signal detection and actionable information to existing DoD systems. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.	-	-	12.000
Title: BioDesign ***Description:*** BioDesign will employ system engineering methods in combination with advances in biological and chemical technologies to create novel methods for threat response. This thrust will develop new high-throughput technologies for monitoring the function of cellular machinery at the molecular level and the response(s) of that machinery to physical, chemical, or biological threats. While conventional approaches typically require decades of research, new high-throughput approaches will permit rapid assessment of the impact of known or unknown threats on identified biomolecules and cell function. Successful research in this thrust will both reduce the time required to understand the mechanism of action for new pharmaceutical compounds and enhance response capabilities for emerging and engineered threats. ***FY 2018 Plans:*** - Demonstrate the ability to localize relevant molecules and events to all intracellular compartment(s) (e.g., membrane, nucleus, or cytoplasm) upon the application of a challenge compound.	13.265	12.962	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate the ability to identify intracellular components and events that occur within milliseconds after the application of a challenge compound. - Reconstruct and confirm greater than 95 percent of the molecules and mechanistic events that comprise the canonical mechanism of action for a demonstration compound which has been applied to cells. - Demonstrate the ability to detect proteins at low concentrations after exposure to a challenge compound. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Biological Robustness in Complex Settings (BRICS) ***Description:*** The Biological Robustness in Complex Settings (BRICS) program will develop innovative approaches to engineer forensic microbial systems, creating unique microbial signatures for environmental forensic operations. Integrating the fundamental component technologies developed under PE 0601101E, TRS-01, this program will focus on engineering microbial communities, detection signatures, and mechanisms to enable the potential safe deployment of engineered systems in open environments. The resulting technologies will improve the speed and portability of detection and analysis systems for microbiome forensics, thereby enabling the addition of more advanced functions such as identifying objects that have come in contact with a labeled environment of interest. ***FY 2018 Plans:*** - Integrate promising component technologies to engineer forensic microbial communities. - Test the robustness, stability, and safety of newly engineered microbial communities in environments of interest. - Evaluate the utility of forensic microbial communities to determine whether objects have traversed an area of interest. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	12.162	10.962	-
Accomplishments/Planned Programs Subtotals	94.200	112.390	118.132

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	190.624	295.447	333.847	-	333.847	307.073	344.283	364.773	381.683	-	-
ELT-01: *ELECTRONIC TECHNOLOGY*	-	190.624	295.447	141.647	-	141.647	116.623	152.673	172.373	188.973	-	-
ELT-02: *BEYOND SCALING TECHNOLOGY*	-	0.000	0.000	192.200	-	192.200	190.450	191.610	192.400	192.710	-	-

A. Mission Description and Budget Item Justification

The Electronics Technology Program Element is budgeted in the Applied Research Budget Activity because its objective is to develop electronics that make a wide range of military applications possible. The Electronics Technology Project focuses on turning basic advancements into the underpinning technologies required to address critical national security issues and to enable an information-driven warfighter.

Advances in microelectronic device technologies continue to significantly benefit improved weapons effectiveness, intelligence capabilities, and information superiority. The Electronic Technology project therefore supports continued advancement in microelectronics, including electronic and optoelectronic devices, Microelectromechanical Systems (MEMS), semiconductor device design and fabrication, and new materials and material structures. Particular focuses of this work include reducing the barriers to designing and fabricating custom electronics and exploiting improved manufacturing techniques to provide low-cost, high-performance sensors. Programs in this project will also greatly improve the size, weight, power, and performance characteristics of electronic systems; support positioning, navigation, and timing in GPS-denied environments; and develop sensors more sensitive and robust than today's standards.

The Electronic Technology project will also investigate the feasibility, design, and development of powerful devices, including non-silicon-based materials technologies to achieve low-cost, reliable, fast, and secure computing, communication, and storage systems. Rapid design and utilization of these new technologies will be a critical focus of ELT-01, as DoD looks for mechanisms to speed the development and fielding of advanced technologies.

This project has six major focus areas: Electronics, Photonics, MicroElectroMechanical Systems, Architectures, Algorithms, and other Electronic Technology research.

The Beyond Scaling Technology project recognizes that phenomenal advancements in electronics will face the fundamental limits of silicon technology in the early 21st century, presenting a barrier that must be overcome in order for progress to continue. This project will therefore pursue potential electronics performance advancements that do not rely on Moore's Law but instead leverage circuit specialization, to include leveraging materials, architectures, and designs that are designed to suit a specific need. Programs within the Beyond Scaling Technology project will look at reducing barriers to making specialized circuits in today's silicon hardware. They will also explore alternatives to traditional circuit architectures, for instance by exploiting chip-scale heterogeneous integration of differing material technologies, using "sticky logic" devices that combine computation and memory functions, and vertical circuit integration to optimize electronic devices. This Project is not a new start. It aggregates and continues Beyond Scaling programs that were initiated in PEs/Projects 0602716E/ELT-01 and 0602303E/IT-02 and IT-03.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	221.911	295.447	234.685	-	234.685
Current President's Budget	190.624	295.447	333.847	-	333.847
Total Adjustments	-31.287	0.000	99.162	-	99.162
• Congressional General Reductions	-15.000	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	-6.110	0.000			
• SBIR/STTR Transfer	-10.177	0.000			
• TotalOtherAdjustments	-	-	99.162	-	99.162

Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction, reprogrammings and the SBIR/STTR transfer.

FY 2018: N/A

FY 2019: Increase reflects expanded focus in the Beyond Scaling Technology Project supporting the Electronics Resurgence Initiative (ERI) offset by decreases in Electronic Technology.

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COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
ELT-01: *ELECTRONIC TECHNOLOGY*	-	190.624	295.447	141.647	-	141.647	116.623	152.673	172.373	188.973	-	-

A. Mission Description and Budget Item Justification

The Electronics Technology Program Element is budgeted in the Applied Research Budget Activity because its objective is to develop electronics that make a wide range of military applications possible. The Electronics Technology Project focuses on turning basic advancements into the underpinning technologies required to address critical national security issues and to enable an information-driven warfighter.

Advances in microelectronic device technologies continue to significantly benefit improved weapons effectiveness, intelligence capabilities, and information superiority. The Electronic Technology project therefore supports continued advancement in microelectronics, including electronic and optoelectronic devices, Microelectromechanical Systems (MEMS), semiconductor device design and fabrication, and new materials and material structures. Particular focuses of this work include reducing the barriers to designing and fabricating custom electronics and exploiting improved manufacturing techniques to provide low-cost, high-performance sensors. Programs in this project will also greatly improve the size, weight, power, and performance characteristics of electronic systems; support positioning, navigation, and timing in GPS-denied environments; and develop sensors more sensitive and robust than today's standards.

The Electronic Technology project will also investigate the feasibility, design, and development of powerful devices, including non-silicon-based materials technologies to achieve low-cost, reliable, fast, and secure computing, communication, and storage systems. Rapid design and utilization of these new technologies will be a critical focus of ELT-01, as DoD looks for mechanisms to speed the development and fielding of advanced technologies.

This project has six major focus areas: Electronics, Photonics, MicroElectroMechanical Systems, Architectures, Algorithms, and other Electronic Technology research.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC)	13.000	18.000	11.803
Description: The High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) program seeks to develop compact Radio Frequency (RF) signal amplifiers for air, ground, and ship-based communications and sensing systems. HAVOC amplifiers would enable these systems to access the high-frequency millimeter-wave portion of the Electromagnetic (EM) spectrum, facilitating increased range and other performance improvements. Today, the effectiveness of combat operations across all domains increasingly depends on DoD's ability to control and exploit the EM spectrum and to deny its use to adversaries. However, the proliferation of inexpensive commercial RF sources has made the EM spectrum crowded and contested, challenging our spectrum dominance. Operating at higher frequencies, such as the millimeter-wave, helps DoD to overcome these issues and offers numerous tactical advantages such as high data-rate communications and high resolution and sensitivity for radar and sensors. Opportunities for transferring HAVOC technology to the Services will be identified during the			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
execution of the early phases of the program. Technology transfer efforts will follow a spiral development process to mitigate risk and provide the opportunity to incorporate new technological developments as they occur. Basic research for this program is funded within PE 0601101E, Project ES-01. ***FY 2018 Plans:*** - Design, fabricate, and test wide bandwidth vacuum windows with high power handling capability. - Investigate new magnetic materials and magnet configurations that enable compact, integrated beam focusing and transport architectures. - Integrate components into prototype amplifiers and begin testing. ***FY 2019 Plans:*** - Design, fabricate, and test higher power, higher duty cycle devices to meet advanced program metrics. - Research novel techniques and technologies to address greater thermal management requirements of higher power devices. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the shift from integration of components to final testing.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM)	13.624	20.500	14.844
Description: The Precise Robust Inertial Guidance for Munitions (PRIGM) program aims to develop inertial sensor technologies for positioning, navigation, and timing (PNT) in GPS-denied environments. When GPS is not available, these inertial sensors can provide autonomous PNT information. The program will exploit recent advances in integrating photonic (light-manipulating) components into electronics and in employing Microelectromechanical Systems (MEMS) as high-performance inertial sensors for use in extreme environments. Whereas conventional MEMS inertial sensors can suffer from inaccuracies due to factors such as temperature sensitivity, new photonics-based PNT techniques have demonstrated the ability to reject these inaccuracies. PRIGM will focus on two areas. By 2020, it aims to develop and transition a Navigation-Grade Inertial Measurement Unit (NGIMU), a state-of-the-art MEMS device, to DoD platforms. By 2030, it aims to develop Advanced Inertial MEMS Sensors (AIMS) that can provide gun-hard, high-bandwidth, high dynamic range navigation for GPS-free munitions. These advances should enable navigation applications, such as smart munitions, that require low-cost, size, weight, and power inertial sensors with high bandwidth, precision, and shock tolerance. PRIGM will advance state-of-the-art MEMS gyros from TRL-3 devices to a TRL-6 transition platform, eventually enabling the Service Labs to perform TRL-7 field demonstrations. Basic research for this program is funded within PE 0601101E, Project ES-01 and advanced technology development for the program is budgeted in PE 0603739E, Project MT-15. ***FY 2018 Plans:*** - Design and fabricate heterogeneously integrated, chip-scale waveguide optical gyroscopes.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate navigation grade accuracy and stability of integrated inertial sensors. ***FY 2019 Plans:*** - Package all component technology and test photonic-MEMS inertial sensor performance robustness to environmental temperature variation for repeatability between routine operations. - Demonstrate inertial sensor survival and operation through laboratory-representative launch events. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects completion of design to transition of packaging component technology and testing inertial sensor performance.			
Title: Wafer-scale Infrared Detectors (WIRED)	14.000	19.000	18.500
Description: The WIRED program addresses the need for low-cost, high-performance imaging sensors in the short-wave and mid-wave infrared (SWIR/MWIR) bands. These sensors will provide increased standoff distances for small unmanned aerial vehicles, low-cost missiles, handheld weapon sights and surveillance systems, helmet-mounted systems, and ground-vehicle-mounted threat warning systems. WIRED proposes to manufacture these sensors at the wafer scale, which reduces costs by processing dozens to hundreds of camera imaging arrays at a time. Wafer-scale manufacturing has already driven a revolution in optical imaging in the Long-Wave Infrared Thermal (LWIR) spectrum, with high-resolution digital cameras and LWIR sensors having become commonplace or widely-available. However, no similar technologies exist for the SWIR/MWIR bands. WIRED could therefore drive a similar revolution in SWIR/MWIR. The program aims to significantly reduce the weight and volume of MWIR detectors, which today require heavy cryogenic cooling systems, and increase the resolution of SWIR detectors by dramatically reducing their pixel size relative to the state-of-the-art. ***FY 2018 Plans:*** - Demonstrate improved imaging from MWIR detectors that are integrated directly onto readout integrated circuits (ROICs) and evaluate detector performance/characteristics at temperatures of 250 K. - Demonstrate improved imaging from small pixel SWIR detectors that are integrated directly onto ROICs and evaluate detector performance/characteristics. - Update cost models based on detector performance. - Demonstrate performance of a LWIR device at temperatures of 298 K. ***FY 2019 Plans:*** - Demonstrate an integrated MWIR camera and evaluate performance at temperature of 270 K. - Demonstrate an integrated small-pitch SWIR camera and optimize design of high-resolution SWIR camera.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate performance of a LWIR device array and demonstrate improved performance at 298 K. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects minor program repricing.			
Title: Modular Optical Aperture Building Blocks (MOABB) ***Description:*** The Modular Optical Aperture Building Blocks (MOABB) program aims to greatly improve the cost, size, weight, and performance of free-space optical systems. These systems enable applications such as Light Detection And Ranging (LIDAR), laser communications, laser illumination, navigation, and 3D imaging. Specifically, MOABB will construct millimeter-scale optical building blocks that can be coherently arrayed to form larger, higher power devices. These building blocks would replace the traditional large and expensive precision lenses and mirrors, which require slow mechanical steering, that form conventional optical systems. MOABB will develop scalable optical phased arrays that can steer light waves without the use of mechanical components. These advances would allow for a 100-fold reduction in size and weight and a 1,000-fold increase in the steering rate of optical systems. ***FY 2018 Plans:*** - Demonstrate beam steering using photonic phase shifters and wavelength tuning in low-loss waveguide gratings. - Demonstrate a scalable unit cell with integrated amplification. - Complete preliminary LIDAR system designs. ***FY 2019 Plans:*** - Demonstrate frequency modulated LIDAR functionality of a unit cell. - Coherently combine light between multiple unit cells. - Demonstrate synthesis of multiple light beams generated from a common aperture. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects minor program repricing.	16.911	22.000	23.000
Title: Atomic Clock with Enhanced Stability (ACES) ***Description:*** The Atomic Clock with Enhanced Stability (ACES) program aims to develop extremely stable chip-scale atomic clocks for unmanned aerial vehicles and other low size, weight, and power (SWaP) platforms with extended mission durations. Atomic clocks provide the high-performance backbone of timing and synchronization for DoD navigation; communications; electronic warfare (EW); and intelligence, surveillance, and reconnaissance (ISR) systems. However, atomic clocks are limited, particularly by temperature sensitivity, aging over long timescales, and a loss of accuracy when power cycled. By employing alternative approaches to confining and measuring atomic particles, ACES could yield a 100x - 1000x improvement in key performance parameters related to each of these limitations. ACES will also focus on developing the component technologies	10.589	21.000	18.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
necessary for low-cost manufacturing and for deployment in harsh DoD-relevant environments. Among its many benefits, program success could help reduce the risk posed by a growing national dependence on GPS, allowing systems to maintain their timing accuracy in the event of temporary GPS unavailability. ***FY 2018 Plans:*** - Perform laboratory demonstration of functioning ACES clock meeting Phase 1 metrics of power consumption, retrace, and instability. - Design an integrated physics package meeting Phase 2 size, weight, and power (SWaP) objectives. - Initiate fabrication and testing of an integrated physics package meeting the ACES Phase 2 SWaP, retrace, aging, and instability. ***FY 2019 Plans:*** - Complete fabrication and testing of an integrated physics package meeting the ACES Phase 2 SWaP, retrace, aging, and instability goals. - Deliver prototype physics package and supporting electronics to government facility for testing. - Design an integrated physics package meeting Phase 3 SWaP objectives. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects ACES completing fabrication and conducting final testing for transition to the Service Labs for further development.			
Title: Limits of Thermal Sensors (LOTS)	9.000	9.000	9.000
Description: The Limits of Thermal Sensors (LOTS) program aims to demonstrate long-wave infrared (LWIR) detector technologies with both high performance and low-size, weight, power, and cost (SWaP-C). The resulting technologies would enable improvements in imaging systems such as night-vision goggles, infrared-guided missiles, and missile threat warning systems. Currently, LWIR-enabled systems must choose between large and expensive cryogenically-cooled detectors, which offer high sensitivity and low response times, and uncooled detectors called microbolometers, which offer significant SWaP-C reductions at lower performance. LOTS seeks to develop microbolometers that can compete with larger cameras in terms of higher sensitivity required to detect signals over long ranges and lower response time required to avoid image blur. These technologies will allow DoD to deploy smaller, lighter, and cheaper sensors on critical, high-value assets while maintaining or improving their ability to engage fast-moving or distant targets. ***FY 2018 Plans:*** - Build LWIR cameras using LOTS microbolometer designs and demonstrate 2x improvement over state of the art using the microbolometer figure of merit.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Test cameras for radiometric performance and sensitivity and deliver camera hardware. ***FY 2019 Plans:*** - Build LWIR cameras with refined sensors to meet final program specifications. - Validate test camera sensitivity and response time in a relevant application environment.			
Title: Direct On-Chip Digital Optical Synthesis (DODOS) ***Description:*** The Direct On-chip Digital Optical Synthesis (DODOS) program will integrate diverse electronic and photonic components to create a compact, robust, and highly-accurate optical frequency synthesizer for various mission-critical DoD applications. Frequency synthesis and accurate control of radiofrequency and microwave radiation is the enabling technology for radar, satellite and terrestrial communications, positioning and navigation technology, and many other core DoD capabilities. Frequency synthesis and control of light or optical waves, however, has been constrained to laboratory experiments due to the size, fragility, and cost of optical frequency synthesizers. DODOS will leverage recent developments in the field of integrated photonics to enable the development of a ubiquitous, low-cost optical frequency synthesizers. The program could lead to disruptive DoD capabilities, including high-bandwidth optical communications, higher performance Light Detection And Ranging (LiDAR), portable high-accuracy atomic clocks, and high-resolution detection of chemical/biological threats at a distance. Basic research for this program is funded within PE 0601101E, Project ES-01. ***FY 2018 Plans:*** - Develop DODOS photonics packaging architectures and deliver prototypes with integrated photonic chips compatible with large-scale batch manufacturing. - Improve the long-term stability of the miniaturized DODOS prototypes and demonstrate synthesizer performance meeting the Phase 2 program goals. ***FY 2019 Plans:*** - Successful field demonstration of co-integrated optical frequency synthesizer and control electronics on the DODOS prototype. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects final demonstration of the DODOS prototype.	10.000	13.000	6.000
Title: Atomic Magnetometry for Biological Imaging In Earth's Native Terrain (AMBIIENT) ***Description:*** The Atomic Magnetometry for Biological Imaging In Earth's Native Terrain (AMBIIENT) program will develop novel magnetic sensors capable of providing high-sensitivity signal measurements in the presence of ambient magnetic fields. In recent years, the value of magnetic imaging, for example for cardiac and other biological signals, has shown tremendous potential for advanced research and clinical diagnosis. Practical application, however, has been limited. Interference from natural and manmade ambient magnetic fields has required that the measurements be performed in specialized, magnetically-shielded	-	12.000	13.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
research facilities. The AMBIIENT program will exploit novel physical architectures that are resistant to the impact of common noise sources. The AMBIIENT sensor itself must be able to detect the gradient of a local magnetic field while subtracting the much larger ambient signal. This would enable low-cost, portable, high-sensitivity measurements for in-the-field applications. In addition to medical research and clinical diagnosis, AMBIIENT sensors promise to enable diverse sensing applications including magnetic gradient navigation, anomaly detection, perimeter monitoring, and Ultralow Frequency (ULF) communications. ***FY 2018 Plans:*** - Develop preliminary architectures for direct gradient sensing of magnetic fields. - Develop and test quantitative models of gradient sensor physics. - Perform laboratory validation of proof-of-principle gradient sensor physics performance. ***FY 2019 Plans:*** - Fabricate and test preliminary architectures for direct gradient sensing of magnetic fields. - Refine quantitative models of gradient sensor physics. - Perform laboratory testing of proof-of-principle gradient sensor physics package meeting AMBIIENT Phase 1 size weight and power, accuracy, and sensitivity goals. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects minor program repricing.			
Title: Dynamic Range-enhanced Electronics and Materials (DREaM) ***Description:*** The Dynamic Range-enhanced Electronics and Materials (DREaM) program aims to develop intrinsically linear (ideal) radio frequency (RF) transistors with improved power efficiency and extremely high dynamic range. Linearity, power efficiency, and dynamic range are fundamental characteristics that allow RF systems to reliably transmit clear signals. Improving these characteristics is essential to operating in a crowded RF environment and to enabling next-generation communication, sensing, and electronic warfare systems. Traditional RF transistor designs typically require a trade-off between linearity and broadcast power, and poor linearity results in undesired interference. DREAM will overcome this tradeoff by employing new transistor materials, architectures, and designs. The resulting DREAM-enabled technologies will allow future RF electronics to increase their operating range without polluting the already-congested RF spectrum and while consuming less system power. ***FY 2018 Plans:*** - Explore novel device structures and emerging materials that will result in high power, high linearity and high power efficiency RF transistors.	-	14.000	18.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop high power and linear power transistor prototype that provides three times more power density and linearity than the state of the art. ***FY 2019 Plans:*** - Develop initial low noise and lower power linear transistor prototype that provides 10 times improvement of linearity figure of merit than the state of the art. - Develop fabrication processes for initial advanced transistor architectures and complete early characterization of RF transistor prototypes with two times improvement in output power over the state of the art. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the need to fund a more diverse portfolio to facilitate alignment with DoD mission needs and support an increased number of RF transistor prototype deliverables for characterization by the government.			
Title: Wireless Autonomous Vehicle Power Transfer (WAVPT) ***Description:*** The Wireless Autonomous Vehicle Power Transfer (WAVPT) program will develop small footprint, efficient receivers to enable power beaming from a ground-based transmitter to a remote unmanned aerial vehicle (UAV). UAVs are currently powered by large, heavy chemical batteries or an engine, with associated liquid fuel. This consumes a large percentage of the UAV's weight budget and places strict limitations on its range. Wireless power transfer represents a paradigm-changing solution to power distribution by alleviating the need to carry all energy sources on-board, drastically reducing UAV weight, and increasing aircraft endurance. Additional power can also be made available for the UAV's payload, allowing use of higher-functionality sensing and computing systems and enabling better data exploitation and threat response. Previous wireless power transfer experiments have demonstrated delivery of over 30 kilowatts of power over a distance of one kilometer but have seen limited adoption due to the prohibitively large, meter-sized receivers required. WAVPT will leverage recent advances in directed energy sources and beam-forming capabilities and develop new receiver architectures to demonstrate efficient wireless power transfer in a small form-factor. Advanced semiconductor materials and processing techniques will be used to develop low-cost, centimeter-sized receivers with high efficiency and energy densities, enabling integration within a small platform. The program will culminate with a demonstration of hundreds of watts of power being transferred from a ground-based transmitter to a UAV at least one kilometer away. The technology that is developed within this program can break the inherent tradeoff between mission duration and weight for unmanned vehicles and transform next-generation military systems. ***FY 2018 Plans:*** - Devise a detailed Concept of Operations (CONOPs) for wireless power beaming, including selected UAV, dwell time needed for charging, payload power requirements, and platform integration. - Identify link budget for wireless power transfer over one kilometer.	-	9.000	9.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate a proof of concept flight demo using commercial components. ***FY 2019 Plans:*** - Design a custom high-power, high-efficiency, receiver architecture for mission-required beam transmission. - Complete designs and begin component development for a custom integrated wireless power system integrated with a Group 2/3 UAV. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects minor program repricing.			
Title: Arrays at Commercial Timescales (ACT) ***Description:*** The Arrays at Commercial Timescales (ACT) program will develop standardized, fully digital phased array system components to enable rapid upgrades to DoD communications, electronic warfare, and radar systems. Phased arrays, which control and steer radio signals, have helped the DoD maintain technological superiority in nearly every theater of conflict. However, current phased array components are based on custom analog electronics, making them expensive to develop, difficult to upgrade, and time-consuming to deploy. ACT will address this challenge by leveraging programmable, commercial-off-the-shelf, digital components that can undergo yearly technology refreshes in response to a continually changing threat environment. This approach can dramatically reduce the time and cost required to develop and update DoD phased arrays. Further, the ongoing cost reductions and performance improvements typical in the commercial sector could enable the DoD to place phased arrays on inexpensive platforms such as Unmanned Aerial Vehicles where they have previously proven prohibitively expensive to develop or maintain. ***FY 2018 Plans:*** - Demonstrate arbitrary control of the surface current in a 16 element antenna array. - Continue development of the ACT common module using an advanced 14 nm process node and demonstrate performance improvement compared to the common module developed using a 32 nm node in Phase 1. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects program completion.	13.000	10.000	-
Title: Adaptive Radio Frequency Technology (ART) ***Description:*** The Adaptive Radio Frequency Technology (ART) program developed a technology base to enable real-time-adaptable radios for individual warfighters and small unmanned systems. ART technologies provided capabilities for next-generation communications, sensing, and electronic warfare, including reconfigurable radios and efficient and compact signal identification capabilities. Goals of the ART program included (1) developing a technology base enabling future radios to survey and adapt to the electromagnetic environment; (2) enabling the rapid deployment of radios in response to changing operational	5.000	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
requirements; and (3) significantly reducing the size, weight, and power (SWaP) of such radios. ART enabled the use of a single design pathway for multiple, unique radio frequency (RF) systems, thus dramatically reducing military procurement and sustainment costs. ART also advanced the hardware and software used in radio frequency (RF) systems by developing a flexible, reconfigurable architecture that can adapt to various RF waveforms.			
Title: Diverse & Accessible Heterogeneous Integration (DAHI) ***Description:*** The Diverse Accessible Heterogeneous Integration (DAHI) program developed the design and manufacturing capabilities required to seamlessly integrate various semiconductors, microelectromechanical systems, photonic (light-manipulating) devices, and thermal management structures into true systems-on-a-chip (SOC). This capability enabled dramatic size, weight, and volume reductions and higher performance for DoD electronic warfare, communications, and radar systems. Historically, chip designers had to decide between the availability, development, and low cost of silicon circuits or the high performance of compound semiconductor (CS) materials. DAHI, however, built on previous DARPA and commercial efforts, which demonstrated that heterogeneously integrating CS and silicon can yield significant performance improvements over silicon or CS alone. DAHI's applied research program focused on developing and demonstrating high-performance SOC for DoD-specific applications. The program also enhanced the manufacturing yield and reliability of heterogeneous integration capabilities and demonstrated innovative, advanced microsystems that leveraged heterogeneous integration. Relevant manufacturing processes were made available to a wide variety of designers from the DoD laboratories, federally funded research and development centers, academia, and industry. This program had advanced technology development efforts funded in PE 0603739E, Project MT-15.	7.000	-	-
Title: Vanishing Programmable Resources (VAPR) ***Description:*** The Vanishing Programmable Resources (VAPR) program created microelectronic and mechanical systems capable of physically vanishing in a controlled, triggerable manner. This advance helped avoid problems associated with unrecovered devices, including their potential use by unauthorized individuals and the compromise of intellectual property. The resulting technologies enabled a range of applications including vanishing sensors for monitoring large areas of the environment and transient airborne vehicles for emergency resupply without requiring pack out of the air delivery vehicle. To support this new class of electronics and mechanical structures, VAPR developed and established an initial set of transient materials and components along with the required manufacturing processes. The resulting systems performed comparably to commercial-off-the-shelf systems while demonstrating system transience that can be programmed, adjusted, triggered, or made to respond to the deployment environment. VAPR technologies were demonstrated through two final test platforms. A vanishing air delivery vehicle capable of precise, gentle drops of small payloads (~3 lbs.) demonstrated the feasibility of transient structural materials. A sensor with a wireless link demonstrated the manufacturability of transient electronics. Both demonstrations were intended to	9.000	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
fully function on their own and to serve as a leading indicator of the potential systems and concepts-of-operation that VAPR could enable.			
Title: Common Heterogeneous integration & IP reuse Strategies (CHIPS) ***Description:*** The Common Heterogeneous integration & IP reuse Strategies (CHIPS) program aims to develop the design tools and integration standards required to better leverage leading-edge commercial sector technologies in DoD systems. The program aims to realize modular Integrated Circuits (ICs) that integrate designs using different commercial suppliers and silicon technologies. CHIPS will therefore pursue standardized interfaces for integrating a variety of Intellectual Property (IP) blocks in the form of prefabricated chiplets. The chiplets could be reused across applications, manufacturers, and transistor types, allowing DoD to amortize IC design costs across programs, better align electronics design and fabrication with military performance goals, and expand beyond its traditional reliance on the proprietary capabilities of a few on-shore manufacturers. ***FY 2018 Plans:*** - Finalize selection of standards for high-bandwidth interfaces of digital chiplet-based interconnections. - Complete design activities of heterogeneous circuit demonstrations to verify interface standards for chiplet-based integration of digital IP blocks, including commercial and DoD blocks. - Initiate fabrication of heterogeneous circuit demonstrations to verify interface standards for chiplet-based integration of digital IP blocks, including commercial and DoD blocks. - Continue the study of the system level impact of IP re-use for the optimal use of digital functional blocks. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to Project ELT-02.	28.500	28.000	-
Title: Near Zero Energy RF and Sensor Operations (N-ZERO) ***Description:*** The Near Zero Power RF and Sensor Operations (N-ZERO) program will develop and demonstrate the technologies required to extend the lifetimes of remotely-deployed sensors from months to years. Today's state-of-the-art sensors can be pre-placed and remain dormant until awoken by an external trigger or stimulus. However, the active electronics that monitor for external triggers consume power, limiting sensor lifetimes to between weeks and months. N-ZERO seeks to replace these electronics with passive or extremely low-power devices that continuously monitor the environment and wake up active electronics upon detection of a specific trigger. This would eliminate or significantly reduce standby power consumption, ensuring that sensor lifetimes are limited only by the power required to process and communicate confirmed events. In doing so, N-ZERO could enable wireless sensors with drastically increased mission life and help meet DoD's unfulfilled need for a persistent, event-driven sensing capability. N-ZERO's applied research component will focus on developing radio frequency (RF) communications and physical	15.000	20.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
sensor systems that use energy from an external trigger to collect, process, and detect useful information while rejecting spurious signals and noise. A basic research component is budgeted under PE 0601101E, Project ES-01. ***FY 2018 Plans:*** - Design, fabricate and evaluate microsystems enabling passive or near zero energy collection, processing and detection of RF communications and physical sensor signatures at reduced (100x lower than the original specifications) signal strength. - Identify and engage potential users in the national security space to develop N-ZERO transition opportunities. - Initiate development of a near zero power wake-up circuit designed for a specific DoD application. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to Project ELT-02.			
Title: Circuit Realization At Faster Timescales (CRAFT)	26.000	25.947	-
Description: The Circuit Realization At Faster Timescales (CRAFT) program will develop novel integrated circuit (IC) design flows to reduce by ten times the design and verification effort required for high-performance military electronics. CRAFT will also reduce barriers to the design and fabrication of custom ICs in leading-edge complementary metal oxide semiconductor (CMOS) technology. When selecting electronics for advanced systems, DoD currently must choose between high-performing custom ICs that take years to design and verify or significantly lower-performing general purpose ICs that can be implemented in a few months. The need to protect sensitive IC information further limits DoD's ability to access certain leading-edge commercial electronics. To reduce the design and verification effort, CRAFT will investigate and leverage novel design flows that utilize recent advances in electronic design automation and software design methodologies. These design flows could reduce the manual labor required to develop and verify custom ICs. CRAFT will also explore increased design reuse and flexibility, which will allow DoD to migrate chip fabrication between different foundries or to more advanced technology nodes. Finally, CRAFT will develop and validate various techniques for obscuring sensitive information during the IC manufacturing process, allowing DoD to leverage more of the available onshore semiconductor market. These capabilities can help to ensure that the DoD has multiple potential suppliers for critical ICs and help keep military electronics at the leading edge. ***FY 2018 Plans:*** - Complete initial testing of at least one full object oriented design flow. - Complete third Fin Field Effect Transistor (FinFET) multi-project wafer shuttle run. - Complete FinFET design fabrication on multiple technology nodes at multiple foundries. - Evaluate designs from the second and third multi-project wafer shuttle runs. - Utilize design flow and intellectual property (IP) from the CRAFT repository to complete a DoD reference design.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-01 / *ELECTRONIC TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Mature new and existing IP obfuscation techniques, evaluate them on DoD-relevant chips, and develop the technologies and techniques required to deploy them for DoD needs. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to Project ELT-02.			
Title: Beyond Scaling - Materials ***Description:*** The Beyond Scaling - Materials program will demonstrate the integration of novel materials into next-generation logic and memory components. Historically, the DoD had taken the lead in shaping the electronics field through research in semiconductor materials, circuits, and processors. However, as DoD focuses on military-specific components and commercial investments eschew the semiconductor space, U.S. fundamental electronics research is stagnant just as an inflection point in Moore's Law (silicon scaling) is about to occur. This program will pursue potential enhancements in electronics that do not rely on Moore's Law, including research not only into new materials but also into the implications of those materials at the device, algorithm, and packaging levels. Research areas will include heterogeneous integration of multiple materials, "sticky logic" devices that combine elements of computation and memory, and leveraging three-dimensional vertical circuit integration to demonstrate dramatic performance improvements with older silicon technologies. The program aims to demonstrate the manufacturability of functioning switches, memory, and novel computational units in a large-scale system. Previous DARPA work on unconventional computing, integration, and reprogrammable memory give confidence in this approach. Basic research for this program is funded within PE 0601101E, Project ES-01. ***FY 2018 Plans:*** - Quantify the value of monolithic vertical integration using leading-edge modern and older technology nodes. - Demonstrate the ability to store the results of computer processing in close proximity to computer logic blocks. - Demonstrate use of unconventional components and designs for non-Von Neumann compute architectures. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to Project ELT-02.	-	19.000	-
Title: Beyond Scaling - Architectures and Designs ***Description:*** The Beyond Scaling - Architectures and Designs program will significantly increase the ease with which DoD can design, deliver, and eventually upgrade critical, customized electronics hardware. As Moore's Law slows and the nation loses the benefit of free, exponential improvements in electronics cost, speed, and power derived from silicon scaling, the DoD will need to maximize the benefits of available silicon technologies by using design tools that enable circuit specialization. This program will develop and demonstrate the tools required for rapidly designing and deploying specialized circuits. Research efforts will explore technologies and techniques such as new domain-specific circuit architectures; co-design of electronics hardware and software;	-	35.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-01 / *ELECTRONIC TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
tight integration of chip-scale processing blocks and artificial intelligence-enabled processing controllers; and open-source circuit designs. Further research will also develop tools to create exact representations of outdated hardware in the field and to rapidly, cheaply, and safely upgrade these systems with next-generation electronics. Two fundamental goals of this program include (1) reduce the barrier to entry for Complex System on a Chip (SoC) design and (2) manage the utilization of the specialized hardware by enabling the writing of a common code base on top of the customized hardware. Advances under this program will demonstrate a new DoD capability to create specialized hardware and provide benefits by improving electronics systems that do not depend on continued rapid improvements in silicon transistors. Basic research for this program is funded within PE 0601101E, Project ES-01. ***FY 2018 Plans:*** - Demonstrate concepts for machine generation of physical objects that would provide a dramatic reduction in circuit design time. - Demonstrate the ability to construct a system with decomposable pieces that can be rapidly upgraded. - Establish and exhibit the capability to manage specialized accelerators for a variety of codes and applications. - Develop programming language and compiler approaches for dynamic data-dependent optimization of hardware configuration. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to Project ELT-02.			
Accomplishments/Planned Programs Subtotals	190.624	295.447	141.647

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602716E / *ELECTRONICS TECHNOLOGY*	Project (Number/Name) ELT-02 / *BEYOND SCALING TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
ELT-02: *BEYOND SCALING TECHNOLOGY*	-	0.000	0.000	192.200	-	192.200	190.450	191.610	192.400	192.710	-	-

A. Mission Description and Budget Item Justification

The Beyond Scaling Technology project recognizes that phenomenal advancements in electronics will face the fundamental limits of silicon technology in the early 21st century, presenting a barrier that must be overcome in order for progress to continue. This project will therefore pursue potential electronics performance advancements that do not rely on Moore's Law but instead leverage circuit specialization, to include leveraging materials, architectures, and designs that are designed to suit a specific need. Programs within the Beyond Scaling project will look at reducing barriers to making specialized circuits in today's silicon hardware. They will also explore alternatives to traditional circuit architectures, for instance by exploiting chip-scale heterogeneous integration of differing material technologies, using "sticky logic" devices that combine computation and memory functions, and vertical circuit integration to optimize electronic devices. This Project is not a new start. It aggregates and continues Beyond Scaling programs that were initiated in PEs/Projects 0602716E/ELT-01 and 0602303E/IT-02 and IT-03.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Beyond Scaling - Materials	-	-	33.254
Description: The Beyond Scaling - Materials program will demonstrate the integration of novel materials into next-generation logic and memory components. Historically, the DoD had taken the lead in shaping the electronics field through research in semiconductor materials, circuits, and processors. However, as DoD focuses on military-specific components and commercial investments eschew the semiconductor space, U.S. fundamental electronics research is stagnant just as an inflection point in Moore's Law (silicon scaling) is about to occur. This program will pursue potential enhancements in electronics that do not rely on Moore's Law, including research not only into new materials but also into the implications of those materials at the device, algorithm, and packaging levels. Research areas will include heterogeneous integration of multiple materials, "sticky logic" devices that combine elements of computation and memory, and leveraging three-dimensional vertical circuit integration to demonstrate dramatic performance improvements with older silicon technologies. The program aims to demonstrate the manufacturability of functioning switches, memory, and novel computational units in a large-scale system. Previous DARPA work on unconventional computing, integration, and reprogrammable memory give confidence in this approach. Basic research for this program is funded within PE 0601101E, Project ES-02. ***FY 2019 Plans:*** - Complete design and initiate fabrication of a significant computation block based on vertically integrated monolithic logic and memory components. - Demonstrate that leading-edge System on a Chip (SoC) performance can be achieved using an older technology node through the use of monolithic vertical integration.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Validate the performance benefits of novel and unconventional circuit topologies which utilize the peculiar physics of unique materials and components not used in traditional silicon processing. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project ELT-01.			
Title: Beyond Scaling - Architectures and Designs ***Description:*** The Beyond Scaling - Architectures and Designs program will significantly increase the ease with which DoD can design, deliver, and eventually upgrade critical, customized electronics hardware. As Moore's Law slows and the nation loses the benefit of free, exponential improvements in electronics cost, speed, and power derived from silicon scaling, the DoD will need to maximize the benefits of available silicon technologies by using design tools that enable circuit specialization. This program will develop and demonstrate the tools required for rapidly designing and deploying specialized circuits. Research efforts will explore technologies and techniques such as new domain-specific circuit architectures; co-design of electronics hardware and software; tight integration of chip-scale processing blocks and artificial intelligence-enabled processing controllers; and open-source circuit designs. Further research will also develop tools to create exact representations of outdated hardware in the field and to rapidly, cheaply, and safely upgrade these systems with next-generation electronics. Two fundamental goals of this program include (1) reduce the barrier to entry for Complex System on a Chip (SoC) design and (2) manage the utilization of the specialized hardware by enabling the writing of a common code base on top of the customized hardware. Advances under this program will demonstrate a new DoD capability to create specialized hardware and provide benefits by improving electronics systems that do not depend on continued rapid improvements in silicon transistors. Basic research for this program is funded within PE 0601101E, Project ES-02. ***FY 2019 Plans:*** - Create software which allows for reduction in design time of 10x for a given design applied to both a chip design and a board design. - Demonstrate that a hardware scheduler will allow for the optimal routing on a specialized integrated circuit in situ of operation. - Design system-on-chips (SOCs) with heterogeneous mix of processors and algorithm accelerators to solve domain-specific compute problems with good power and performance. - Implement an intelligent scheduler to utilize the mix of heterogeneous processors and demonstrate the scheduler on commercially available SOCs. - Demonstrate pathways to apply machine learning to physical design and creation of annotated datasets for machine learning. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project ELT-01.	-	-	67.786
Title: Common Heterogeneous integration & IP reuse Strategies (CHIPS)	-	-	15.500

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Common Heterogeneous integration & IP reuse Strategies (CHIPS) program aims to develop the design tools and integration standards required to better leverage leading-edge commercial sector technologies in DoD systems. The program aims to realize modular Integrated Circuits (ICs) that integrate designs using different commercial suppliers and silicon technologies. CHIPS will therefore pursue standardized interfaces for integrating a variety of Intellectual Property (IP) blocks in the form of prefabricated chiplets. The chiplets could be reused across applications, manufacturers, and transistor types, allowing DoD to amortize IC design costs across programs, better align electronics design and fabrication with military performance goals, and expand beyond its traditional reliance on the proprietary capabilities of a few on-shore manufacturers. ***FY 2019 Plans:*** - Complete module design activities to determine performance and program benefits of new processes enabled by the program. - Initiate fabrication of approved modules to determine performance and program benefits of new processes enabled by the program. - Continue the study of the system level impact of IP re-use for the optimal use of digital and analog functional blocks. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project ELT-01.			
Title: System Security Integrated Through Hardware and firmware (SSITH)	-	-	22.790
Description: The System Security Integrated Through Hardware and firmware (SSITH) program seeks to secure DoD and commercial electronic systems against cybersecurity threats by developing novel hardware/firmware security architectures and hardware design methodologies. Current responses to cybersecurity attacks typically consist of developing and deploying software patches to address specific vulnerabilities in a software firewall without addressing potential vulnerabilities in the underlying hardware architecture. To address this challenge, SSITH will drive new research in electronics hardware security and exploit current research in areas such as cryptographic-based computing and hardware verification. Implementation of these advanced ideas has been enabled by the extremely capable semiconductor technology driven by Moore's Law. The program will also investigate flexible hardware architectures that adapt to and limit the impact of new cybersecurity attacks. Finally, SSITH will seek to mitigate the potential negative impact of new security protection architectures on system performance and power usage. Once developed, SSITH capabilities will be applicable to both commercial and military electronic systems. ***FY 2019 Plans:*** - Implement new hardware architectures on the Field-Programmable Gate Array (FPGA) demonstration platforms that demonstrate scalable, flexible, and robust protection against external attacks on hardware. - Utilize simulation and hardware emulation to confirm the expected improvement in protection of the new hardware architectures relative to current software only protection.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Evaluate SSITH security approaches through independent Red Team attack on the security architectures as implemented on platform FPGA hardware. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from PE 0602303E, Project IT-03.			
Title: Hierarchical Identify Verify Exploit (HIVE) ***Description:*** The Hierarchical Identify Verify Exploit (HIVE) program will pursue new hardware architectures and algorithms for rapidly integrating information from a variety of sources, increasing battlefield situational awareness. To develop operationally significant intelligence, human analysts today watch live battlefield feeds to detect items of interest, fusing together and interpreting information from multiple sensors and sources. The amount of information gathered, however, is quickly outstripping the human ability to review, process, fuse, and interpret. To resolve this challenge, HIVE seeks to leverage improvements in machine learning and artificial intelligence to augment the analyst's ability to integrate large streams of data. The program will investigate advances in chip architecture and data analytics algorithms that can allow machines to infer meaning out of data based on the information needs of the warfighter. Program success would therefore enable the warfighter to understand far more of the battlefield in real time. ***FY 2019 Plans:*** - Improve the toolsets based on information gathered from previous testing and deliver a beta version of the software. - Finalize the chip design and deliver the final design to the chip fabrication facility. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from PE 0602303E, Project IT-02.	-	-	17.600
Title: Circuit Realization At Faster Timescales (CRAFT) ***Description:*** The Circuit Realization At Faster Timescales (CRAFT) program will develop novel integrated circuit (IC) design flows to reduce by ten times the design and verification effort required for high-performance military electronics. CRAFT will also reduce barriers to the design and fabrication of custom ICs in leading-edge complementary metal oxide semiconductor (CMOS) technology. When selecting electronics for advanced systems, DoD currently must choose between high-performing custom ICs that take years to design and verify or significantly lower-performing general purpose ICs that can be implemented in a few months. The need to protect sensitive IC information further limits DoD's ability to access certain leading-edge commercial electronics. To reduce the design and verification effort, CRAFT will investigate and leverage novel design flows that utilize recent advances in electronic design automation and software design methodologies. These design flows could reduce the manual labor required to develop and verify custom ICs. CRAFT will also explore increased design reuse and flexibility, which will allow DoD to migrate chip fabrication between different foundries or to more advanced technology nodes. Finally, CRAFT will develop and	-	-	7.000

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
validate various techniques for obscuring sensitive information during the IC manufacturing process, allowing DoD to leverage more of the available onshore semiconductor market. These capabilities can help to ensure that the DoD has multiple potential suppliers for critical ICs and help keep military electronics at the leading edge. ***FY 2019 Plans:*** - Complete the fourth multi-project wafer shuttle run with the final CRAFT design flow. - Finalize the IP repository design and setup to allow access to a design flow and related IP for DoD use. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project ELT-01.			
Title: Near Zero Energy RF and Sensor Operations (N-ZERO) ***Description:*** The Near Zero Power RF and Sensor Operations (N-ZERO) program will develop and demonstrate the technologies required to extend the lifetimes of remotely-deployed sensors from months to years. Today's state-of-the-art sensors can be pre-placed and remain dormant until awoken by an external trigger or stimulus. However, the active electronics that monitor for external triggers consume power, limiting sensor lifetimes to between weeks and months. N-ZERO seeks to replace these electronics with passive or extremely low-power devices that continuously monitor the environment and wake up active electronics upon detection of a specific trigger. This would eliminate or significantly reduce standby power consumption, ensuring that sensor lifetimes are limited only by the power required to process and communicate confirmed events. In doing so, N-ZERO could enable wireless sensors with drastically increased mission life and help meet DoD's unfulfilled need for a persistent, event-driven sensing capability. N-ZERO's applied research component will focus on developing radio frequency (RF) communications and physical sensor systems that use energy from an external trigger to collect, process, and detect useful information while rejecting spurious signals and noise. A basic research component is budgeted under PE 0601101E, Project ES-01. ***FY 2019 Plans:*** - Design, implement and test signal processing to improve the detection and classification capabilities of N-ZERO sensor systems in the presence of significant background interference. - Facilitate transition opportunities for microsystems enabling passive or near zero energy collection, processing and detection of RF communications and physical sensor signatures at reduced (100x lower than the original specifications) signal strength. - Continue the development of a near zero power wake-up circuit designed for a specific DoD application. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project ELT-01.	-	-	11.079
Title: Ensured Communication Link for Identification Friend or Foe (ECLIFF)	-	-	9.191

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Ensured Communication Link for Identification Friend or Foe (ECLIFF) program aims to provide communication links for Identification Friend or Foe (IFF) capabilities with a reduced radio frequency (RF) signature, improved performance against jamming and interference, and a compact form factor. ECLIFF will address the challenge of identifying friendly assets and personnel in congested electromagnetic environments and in environments where there is a strong penalty for stray radio emissions. The current IFF system operates with a limited instantaneous RF bandwidth (IBW), which makes hiding signals from adversaries difficult and leaves the system vulnerable to jamming and interference. ECLIFF will explore alternative technologies to enable ~25 times greater IBW. These technologies should also enable IFF systems to use alternate channels at higher frequency bands. The resulting ECLIFF system could employ DARPA-developed technologies such as high-speed data converters, heterogeneous integration, and envelope-tracking transmitter technology. The novel combination of these technologies in the final ECLIFF system will be critical for dramatic size, weight, power, and cost reduction and performance improvements. The miniaturization realized with the ECLIFF platform should make the capability useful for both large platforms and portable applications such as unmanned air vehicle, man-portable, and even hand-held devices. The ECLIFF program will culminate with a demonstration of the technology in a relevant environment, lowering the risk for transition to a fielded system. ***FY 2019 Plans:*** - Complete system trade study for IFF solution. - Begin initial design of integrated circuit hardware to implement ECLIFF solution. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects program initiation.			
Title: Digital RF Battlespace Emulator (DRBE) ***Description:*** The Digital RF Battlespace Emulator (DRBE) program aims to develop a large-scale, interactive, emulated radiofrequency (RF) environment, providing DoD with the much needed capability to cost-effectively evaluate adaptive, intelligent, and spatially distributed next-generation RF systems. Current U.S. test infrastructure is no longer able to successfully exercise RF systems in relevant environments, which should account for hundreds of DoD systems coordinating against hundreds of adversary systems. Due to the critical dependency of nearly all platforms and missions on the RF spectrum and the increasingly advanced RF capabilities of peer adversaries, current infrastructure limitations represent a critical capability gap. Existing test approaches are either: 1) small-scale laboratory tests under well controlled but unrealistic conditions or 2) massive training exercises, which occur at most annually due to the required cost and manpower and do not fully collect necessary data. To overcome these limitations, DRBE will leverage advances in massively multi-core computing hardware and high-bandwidth digital cross connects to emulate realistic RF environments that account for RF platform movement, signal propagation effects and delays, signal interference, and interactions between RF systems. DRBE will pursue three technical thrust areas: architecture, massively multi-core computing, and scenario modeling. The resulting test environment should allow plug-and-play connections	-	-	8.000

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
for hundreds of RF systems in a 100 km battlespace test. Multi-system exercises could then be quickly executed through many different combat scenarios and variations, with RF systems employing war reserve modes forbidden during open-air testing. DRBE should therefore serve to develop CONOPS, inform battle plans, and fine-tune the performance of both individual and large groups of RF systems. ***FY 2019 Plans:*** - Conduct architecture scaling analysis to define a solution supporting hundreds of RF systems. - Demonstrate basic physical building blocks that will be able to handle the immense throughput expected. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects program initiation.			
Accomplishments/Planned Programs Subtotals	-	-	192.200

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	180.780	155.406	277.603	-	277.603	379.341	253.434	220.316	178.316	-	-
AIR-01: *ADVANCED AEROSPACE SYSTEMS*	-	180.780	155.406	277.603	-	277.603	379.341	253.434	220.316	178.316	-	-

A. Mission Description and Budget Item Justification

The Advanced Aerospace Systems program element is budgeted in the Advanced Technology Budget Activity because it addresses high pay-off opportunities to provide revolutionary new system capabilities for satisfying current and projected military mission requirements associated with advanced aeronautical systems at dramatically reduced costs. Research and development of integrated system concepts, as well as enabling vehicle subsystems will be conducted. Studies conducted under this project include examination and evaluation of emerging aerospace threats, technologies, concepts, and applications for missiles, munitions, and vehicle systems.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	182.327	155.406	162.028	-	162.028
Current President's Budget	180.780	155.406	277.603	-	277.603
Total Adjustments	-1.547	0.000	115.575	-	115.575
• Congressional General Reductions	-3.000	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	5.811	0.000			
• SBIR/STTR Transfer	-4.358	0.000			
• TotalOtherAdjustments	-	-	115.575	-	115.575

Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction and the SBIR/STTR transfer offset by reprogrammings.
FY 2018: N/A
FY 2019: Increase reflects expanded focus in hypersonics initiatives, including Tactical Boost Glide, Advanced Full Range Engine, and Operational Fires.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Collaborative Operations in Denied Environment (CODE)	28.780	30.106	8.000
Description: The goal of the Collaborative Operations in Denied Environment (CODE) program is to enhance mission performance, reduce cost, confound adversaries, and reduce reliance on space assets for navigation and communication by			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
distributing mission functions such as sensing, communication, precision navigation, kinetic, and non-kinetic effects to small platforms and increasing their level of autonomy. Collaboration of multiple assets offers new possibilities to conduct military missions using smaller air platforms to enhance survivability, reduce overall acquisition cost, create new effects, increase communications range and robustness in denied environments, increase search area, increase areas held at risk, reduce target prosecution reaction time, and provide multi-mission capabilities by combinations of assets. This effort will specifically focus on developing and demonstrating approaches that will expand the mission capabilities of legacy air assets through autonomy and collaborative behaviors, within a standard based open architecture. Potential transition partners include the Air Force, Army, and Navy. ***FY 2018 Plans:*** - Validate next major software releases in flight with increasingly complex demonstration scenarios. - Demonstrate the ability of a single commander to plan and execute an end-to-end mission scenario, including insertion of new objectives, introduction and modification of flight restrictions, and providing authorization to engage simulated targets. - Demonstrate expanded CODE autonomy capability including collaborative strike, jamming, Electro-Optical/Infrared (EO/IR) and passive Radio Frequency (RF) search, battle damage assessment, track fusion, and communications-denied mission execution. - Demonstrate the ability to integrate independently developed software modules based on the published CODE software development toolkit. - Collaborate with operational system owners and other partners to develop early transition opportunities. ***FY 2019 Plans:*** - Perform capstone demonstration involving six live and multiple virtual aircraft executing a complex end-to-end mission scenario with multiple contingency events and limited advanced knowledge of red team positions and tactics. - Complete independent, fully-informed modeling, simulation, and analysis effort to validate final CODE software builds. - Produce final CODE software package with complete software development kit and simulation environment to facilitate technology transfer. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects completion of flight testing and program completion.			
Title: Hypersonic Air-breathing Weapon Concept (HAWC)	49.500	30.000	14.300
Description: The Hypersonic Air-breathing Weapon Concept (HAWC) program is a Joint DARPA / Air Force effort that will develop and demonstrate technologies for an effective and affordable air-launched hypersonic cruise missile. These technologies include advanced air vehicle configurations capable of efficient hypersonic flight, hydrocarbon scramjet-powered propulsion to enable sustained hypersonic cruise, thermal management approaches designed for high-temperature cruise, and affordable			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
system designs and manufacturing approaches. This is a joint program with the Air Force, and HAWC technologies are planned for transition to the Air Force after flight testing is complete. ***FY 2018 Plans:*** - Continue updating test-validated performance databases to anchor demonstration vehicle design. - Complete system critical design of flight demonstration system. - Conduct preliminary traceability assessment between the HAWC demonstration system and the HAWC operational system. - Begin software-in-the-loop testing for the demonstration vehicle. - Continue procurement of hardware for flight demonstration vehicle. - Continue safety of flight certification reviews with the test range. - Begin hardware-in-the-loop testing for the demonstration vehicle. - Continue propulsion testing. - Continue detailed plans for flight testing of the demonstration system. - Begin full-scale thermal-structural testing. - Begin procurement of test assets and test support equipment. - Begin assembly, integration, and test of the flight demonstration vehicle. ***FY 2019 Plans:*** - Complete software-in-the-loop testing for the demonstration vehicle. - Complete hardware-in-the-loop testing for the demonstration vehicle. - Complete flight certification reviews with the test range. - Complete full-scale thermal-structural testing. - Complete flight test planning for the demonstration system. - Continue procurement of test assets and test support equipment. - Continue assembly, integration, and test of demonstration vehicle. - Conduct range safety analysis. - Conduct mission readiness review. - Conduct first flight. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects increase in Air Force funding and commensurate decrease in DARPA funding as program progresses.			
Title: Tactical Boost Glide	22.800	37.600	139.400

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019

Description: The Tactical Boost Glide (TBG) program is a Joint DARPA / Air Force effort that will develop and demonstrate technologies to enable air-launched tactical range hypersonic boost glide systems, including flight demonstration of a vehicle that is traceable to an operationally relevant weapon that can be launched from current platforms. The program will also consider traceability, compatibility, and integration with the Navy Vertical Launch System (VLS). The metrics associated with this objective include total range, time of flight, payload, accuracy, and impact velocity. The program will address the system and technology issues required to enable development of a hypersonic boost glide system considering (1) vehicle concepts possessing the required aerodynamic and aero-thermal performance, controllability and robustness for a wide operational envelope, (2) the system attributes and subsystems required to be effective in relevant operational environments, and (3) approaches to reducing cost and improving affordability for both the demonstration system and future operational systems. TBG capabilities are planned for transition to the Air Force and the Navy.

FY 2018 Plans:
- Complete subsystem and system Critical Design Reviews (CDRs).
- Begin aeroshell thermo-structural testing.
- Conduct component aerothermal testing.
- Continue procurement of hardware for demonstration vehicles.
- Continue software in the loop (SIL) testing.
- Begin hardware in the loop (HWIL) and qualification testing.
- Begin Assembly, Integration, and Test (AI&T).
- Continue detailed flight test and range safety planning, coordination, and documentation.
- Update Technology Maturity Plans (TMPs) and Risk Management Plans (RMPs).

FY 2019 Plans:
- Complete procurement of hardware for demonstration vehicles.
- Complete all risk reduction and qualification testing.
- Complete AI&T of first flight article.
- Complete test readiness review (TRR) for first flight.
- Conduct first flight test and begin post-flight analysis.
- Continue AI&T of remaining test articles.
- Continue detailed flight test and range safety planning, coordination, and documentation.
- Update TMPs and RMPs.
- Develop acquisition study for second TBG performer to evolve an All-Up Round (AUR) design to a critical design level of maturity.
- Select second TBG performer.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Plan and conduct additional aerodynamic and aero-thermodynamic risk reduction testing. - Plan and conduct additional material and thermo-structural risk reduction testing. - Plan and conduct additional materials arc-jet testing. - Update aerodynamics and materials databases based on post-risk reduction test analysis. - Plan additional flight tests for expanded risk reduction. - Procure hardware for additional flight tests and begin AI&T of test articles. - Develop preliminary requirements for a Navy variant AUR. - Conduct trade studies and assess booster and Vertical Launch System (VLS) integration development needs of a Navy variant AUR. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects addition of funds for second performer as well as initiation of effort to develop Navy variant AUR.			
Title: Advanced Full Range Engine (AFRE)	13.500	35.000	53.028
Description: The Advanced Full Range Engine (AFRE) program will establish the feasibility of hypersonic aircraft propulsion through a two-pronged approach. AFRE will demonstrate turbine to Dual Mode Ramjet (DMRJ) transition of a Turbine-Based Combined Cycle (TBCC) propulsion system utilizing an off-the-shelf turbine engine. Large scale components of this complex propulsion system will be developed and demonstrated independently, followed by a full-scale freejet TBCC propulsion system mode transition ground test. Accomplishing these objectives will enable future hypersonic systems resulting in transformational changes in long range strike, high speed Intelligence, Surveillance and Reconnaissance (ISR) and Two-Stage-To-Orbit (TSTO) operations. The anticipated transition partner for this effort is the Air Force. ***FY 2018 Plans:*** - Complete integrated system conceptual design, initiate and complete preliminary design. - Complete design and initiate fabrication of common inlet. - Complete test facility startup assessment. - Complete design and initiate fabrication of full-scale combustor. - Complete design and initiate fabrication of full-scale nozzle. - Complete initial integrated propulsion controls architecture and finalize technology development plans. ***FY 2019 Plans:*** - Complete manufacturing and ground demonstrate full scale combustor. - Complete manufacturing and ground demonstrate turbine with water injection and full scale nozzle. - Complete manufacturing and ground demonstrate common inlet. - Integrated TBCC system Critical Design Review.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Initiate integrated TBCC system assembly. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects performance of ground demonstrations and initiation of integrated system assembly work.			
Title: Vertical Take-Off and Landing (VTOL) Technology Demonstrator	47.700	14.700	4.000
Description: The Vertical Take-Off and Landing (VTOL) Technology Demonstrator program will demonstrate revolutionary improvements in (heavier than air) VTOL air vehicle capabilities and efficiencies through the development of subsystem and component technologies, aircraft configurations and system integration. The program will build and flight test an unmanned 10,000 - 12,000 lb. aircraft capable of sustained speeds in excess of 300 kt, demonstrate system level hover efficiency within 25 percent of the ideal power loading, and a lift-to-equivalent drag ratio no less than ten. Additionally, the demonstrator will be designed to have a useful load of no less than 40 percent of the gross weight with a payload capacity of at least 12.5 percent of the gross weight. A strong emphasis will be placed on the development of elegant, multi-functional subsystem technologies that demonstrate net improvements in aircraft efficiencies to enable new and vastly improved operational capabilities. Technologies developed under this program will be made available to all Services for application to future air systems development. The anticipated transition partners for this effort are the Army, Marine Corps, and Special Operations Forces. ***FY 2018 Plans:*** - Complete testing of aircraft propulsion power generator system to verify electro-mechanical system functionality. - Complete electro-mechanical subsystem testing (Copper Bird) to validate design of fan motors and synchronization with generators. - Initiate hardware/software-in-the-loop testing. - Complete subsystem testing of power generation and distribution system (Iron Bird) to include the turboshaft engine, driveshaft, gearbox, generators, electric power distribution, and electric motor functionality. ***FY 2019 Plans:*** - Complete vehicle management system development and avionics requirements, as well as all elements of ground control and operator/pilot stations. - Select ground and flight test site location(s) and finalize ground and flight test plans. - Complete fabrication and assembly of the full, complete aircraft with integrated systems and subsystems. - Complete all air-worthiness considerations and required documentation. - Complete ground and tie-down testing. - Disassemble aircraft and ship to flight test location. - Initiate flight testing. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 decrease reflects completion of flight testing and program completion.			
Title: Advanced Aerospace System Concepts	3.000	3.000	3.000
Description: Studies conducted under this program examine and evaluate emerging aerospace technologies and system concepts for applicability to military use. This includes the degree and scope of potential impact and improvements to military operations, mission utility, and warfighter capability. Studies are also conducted to analyze emerging aerospace threats along with possible methods and technologies to counter them. The feasibility of achieving potential improvements, in terms of resources, schedule, and technological risk, is also evaluated. The results from these studies are used, in part, to formulate future programs or refocus ongoing work. Topics of consideration include: methods of defeating enemy anti-aircraft attacks; munition technologies to increase precision, range, endurance, and lethality of weapons for a variety of mission sets; novel launch systems; air vehicle control, power, propulsion, materials, and architectures; and payload and cargo handling systems. ***FY 2018 Plans:*** - Conduct enabling technology and sub-system feasibility experiments. - Conduct modeling and simulation of boundary layer transition physics. ***FY 2019 Plans:*** - Perform ground and flight experiments to characterize boundary layer transition physics. - Initiate studies of novel concepts. - Perform technology risk assessments to identify critical enabling technologies.			
Title: Operational Fires	-	-	50.000
Description: The goal of the Operational Fires (OpFires) program is to develop and demonstrate a novel ground-launched system enabling advanced weapons to penetrate modern enemy air defenses and rapidly and precisely engage critical time sensitive targets. This program seeks to develop an advanced booster capable of delivering a variety of payloads at a variety of ranges. Additional considerations include the need for compatible mobile ground launch platforms enabling integration with existing ground forces and infrastructure, and specific system attributes required for rapid deployment and redeployment. The OpFires program will conduct a series of subsystem tests designed to evaluate component design and system compatibility, and culminate in integrated end-to-end flight tests. OpFires will leverage and integrate ongoing investments in hypersonic tactical boost glide vehicles (e.g., DARPA s Tactical Boost Glide (TBG) program) to achieve these objectives. In FY18, this program was funded from PE 0602702E, Project TT-07. ***FY 2019 Plans:*** - Complete ground launch platform Systems Requirements Review (SRR) and Conceptual Design Review (CoDR). - Complete booster propulsion system Preliminary Design Review (PDR).			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Conduct early propulsion system risk reduction testing. - Complete payload trade studies. - Begin Operational Fires integrated system trade studies. - Complete military utility assessment and wargames. - Begin development of technology maturation plans and risk management plans (TMPs and RMPs). - Begin flight test and range safety planning, coordination, and documentation. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY19 increase reflects performance of risk reduction testing and initiation of integrated trade studies and critical design of the system.			
Title: Aircraft and Vehicle IntegrAted Team (AVIATE) ***Description:*** The Aircraft and Vehicle IntegrAted Team (AVIATE) program will design, develop and demonstrate an advanced capability Unmanned Air System (UAS) that is an organic extension of tactical ground vehicles. Current fielded UAS systems require significant infrastructure and manpower to launch and recover, exposing friendly troops to threats while stationary. As a result, small units suffer degraded situational awareness with no overhead capability or delays in air support. A UAS that is an integrated subsystem of a ground vehicle with features to autonomously land, attach, stow, detach, and take-off from its parent ground vehicle while it is on the move would enable on-demand capabilities and drastically improved protection. Ground vehicles could perform traditional UAS missions such as intelligence, surveillance and reconnaissance (ISR) and fires support, as well as unique missions such as electronic attack, sensor emplacement, infrastructure attack, and active protection without having to rely on brigade and theater level assets. This effort will explore design interfaces between the air and ground vehicle, attributes to allow for launch and recovery on the move, and design considerations to enable operations in contested environments. The Army, Navy and Marines are all seeking UAS designs to meet their expeditionary needs and provide runway independence. ***FY 2019 Plans:*** - Explore airframe design concepts of flight demonstration vehicle. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.	-	-	5.875
Title: Tactically Exploited Reconnaissance Node (TERN) ***Description:*** The goal of the Tactically Exploited Reconnaissance Node (TERN) program, a joint effort with the Office of Naval Research, is to develop a systems approach for, and perform technical demonstration of, a Medium-Altitude, Long-Endurance Unmanned Aerial Vehicle (MALE UAV) capability from smaller ships. The program will demonstrate the technology for launch and recovery of large unmanned aircraft capable of providing persistent 24/7 Intelligence, Surveillance, and Reconnaissance	12.000	5.000	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
(ISR) and strike capabilities at long radius orbits. By extending the ISR/strike radius and simultaneously increasing time on station beyond current capabilities from smaller ships, TERN will enable novel operational concepts including maritime surveillance and responsive, persistent deep overland ISR and strike, without requirement for forward basing. To achieve these goals, the program will create new concepts for aircraft launch and recovery, aircraft logistics and maintenance, and aircraft flight in regimes associated with maritime operating conditions. The program will culminate in a launch and recovery demonstration. Application of TERN technologies and operational concepts will enable a novel and cost efficient approach for multiple mission sets. The transition partner is the Navy. ***FY 2018 Plans:*** - Conduct integrated propulsion system testing. - Conduct demonstrator system ground checkout. - Conduct demonstrator system airworthiness assessment. - Conduct demonstrator system instrumentation calibration. - Conduct demonstrator system first flight. - Analyze demonstrator flight test data. - Refine demonstrator system flight control. - Conduct TERN objective system requirements review. - Conduct land-based demonstrator system flight testing. - Update TERN objective system performance models based on demonstrator system performance. - Conduct TERN objective system requirements review. - Conduct demonstrator system envelope expansion flight testing. - Conduct demonstrator transition to and from wing-borne flight testing. - Conduct relative navigation take-off and landing operations. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Aerial Reconfigurable Embedded System (ARES) ***Description:*** Current and future land and ship-to-shore operations require rapid and distributed employment of U.S. forces on the battlefield. The Aerial Reconfigurable Embedded System (ARES) program developed a vertical take-off and landing (VTOL), modular unmanned air vehicle that can carry a 3,000 lb. useful load at a range of 250 nautical miles on a single tank of fuel. ARES will enable distributed operations and access to compact, high altitude landing zones to reduce warfighter exposure to hostile threats and bypass ground obstructions. ARES modular capability allows for mission modules to be quickly interchanged and deployed at the company level. This enables the flexible employment of many different capabilities including: cargo resupply, casualty evacuation, reconnaissance, weapons platforms, and other types of operations. ARES vehicles could be dispatched to	3.500	-	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
resupply isolated small units. ARES is well suited for enhanced company operations concepts that would provide the warfighter/ team increased situational awareness for operations in an urban environment. The enabling technologies of interest developed under the ARES program included vertical and translational flight, conversion between powered lift and wing borne lift, ducted fan propulsion systems, lightweight materials, tailless configuration, modularity, and advanced over-actuated flight controls for stable transition from vertical to horizontal flight. Additionally, the program explored opportunities for the design, development, and integration of new, key technologies and capabilities. These included adaptable landing gear concepts to enable operations from irregular landing zones and moving launch/recovery platforms, and autonomous take off and landing. ARES is transitioning to the Marine Corps.			
Accomplishments/Planned Programs Subtotals	180.780	155.406	277.603

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	162.643	247.435	254.671	-	254.671	190.606	187.726	210.726	237.726	-	-
SPC-01: *SPACE PROGRAMS AND TECHNOLOGY*	-	162.643	247.435	254.671	-	254.671	190.606	187.726	210.726	237.726	-	-

A. Mission Description and Budget Item Justification

The Space Programs and Technology program element is budgeted in the Advanced Technology Development budget activity because it addresses high payoff opportunities to dramatically reduce costs associated with advanced space systems and provides revolutionary new system capabilities for satisfying current and projected military missions.

A space force structure that is robust against attack represents a stabilizing deterrent against adversary attacks on space assets. The keys to a secure space environment are situational awareness to detect and characterize potential threats, a proliferation of assets to provide robustness against attack, ready access to space, and a flexible infrastructure for maintaining the capabilities of on-orbit assets. Ready access to space requires the delivery of capabilities, replenishment of supplies into orbit, and rapid manufacturing of affordable space capabilities. Developing space access and spacecraft servicing technologies will lead to reduced ownership costs of space systems and new opportunities for introducing technologies for the exploitation of space.

Systems development is also required to increase the interactivity of space systems, space-derived information and services with terrestrial users. Studies under this project include technologies and systems that will enable satellites and microsatellites to operate more effectively by increasing maneuverability, survivability, and situational awareness; unique manufacturing or assembly processes, and precision control of multi-payload systems.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	175.240	247.435	271.971	-	271.971
Current President's Budget	162.643	247.435	254.671	-	254.671
Total Adjustments	-12.597	0.000	-17.300	-	-17.300
• Congressional General Reductions	-15.000	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	2.403	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• TotalOtherAdjustments	-	-	-17.300	-	-17.300

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Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction offset by reprogrammings.

FY 2018: N/A

FY 2019: Decrease reflects completion of the Large In-Situ Manufactured Apertures (LIMA) program in FY 2018 and rephasing of the Hallmark program.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Experimental Spaceplane One (XSP)	42.500	61.000	62.000

Description: The goal of the XSP program is to develop and flight demonstrate a prototype booster and expendable upper stage with responsive aircraft-like operations. Past efforts have identified and demonstrated critical enabling technologies including composite or lightweight structures, propellant tanks, thermal protection systems, rocket propulsion and advanced avionics/ software. A critically important technology gap is integration into a flight demonstration able to deliver aircraft-like operability. The program will validate key technologies on the ground, and then fabricate an X-Plane to demonstrate: 1) 10 flights in 10 days, 2) design the objective system for >3000-lb payload at a reduced cost, 3) fly the demonstration system one time with an orbital payload of 900-lbs, and 4) fly to a high staging speed (Mach 3-10). The anticipated transition partners are the Air Force, Navy and commercial sector.

FY 2018 Plans:

- Perform detailed wind tunnel studies of final or near-final aerodynamic design across multiple regimes including subsonic, supersonic, and hypersonic.
- Validate computational analyses to support the finalization of the aerodynamic database used for Guidance, Navigation and Control (GN&C).
- Begin propulsion system integration and preparation for ten engine firings in ten days ground test.
- Mature the XSP concept through tailored Critical Design Review including complete configuration, aerodynamics and aeroheating, six degree of freedom trajectory calculations with flight software in the loop, mass properties and associated ground systems.
- Conduct Critical Design Review to approve XSP vehicle design for component acquisition, fabrication, assembly, and integration.
- Complete propulsion qualification and acceptance testing.
- Complete ten engine firings in ten days ground test.

FY 2019 Plans:

- Complete designs for ground infrastructure.
- Mature range, ground and flight test operations planning.
- Submit commercial spaceport and/or DoD range documentation.
- Begin fabrication of all major subsystems.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Initiate acceptance test planning. - Begin integration and test of major subassemblies, flight and ground systems. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects minor program repricing.			
Title: Radar Net ***Description:*** The Radar Net program will develop lightweight, low power, wideband capability for radio frequency (RF) communications and remote sensing for a space based platform. The enabling technologies of interest are extremely lightweight and space capable deployable antenna structures. Current deployable antenna options have not been sufficiently developed to be dependable on small payload launches, leaving current capabilities trending to large and more costly satellite systems. These satellite systems are expected to have long operational lifetimes, which can leave them behind the pace of state-of-the-art technical developments. The technologies developed under Radar Net will enable small, low-cost sensor payloads on short timescales with rapid technology refresh capabilities. The anticipated transition partner is the Air Force. ***FY 2018 Plans:*** - Conduct risk reduction deployable antenna CDR. - Conduct risk reduction demonstration of multiple deployable antenna technologies. - Demonstrate software-defined radio (SDR) RF capability in relevant environments. - Perform risk reduction signal processing demonstration. - Perform deployable pathfinder demonstration in a relevant environment. - Integrate results from applications study and demonstration/risk reduction into prototype design. - Complete demonstration system Preliminary Design Review (PDR). - Complete demonstration system Critical Design Review (CDR). ***FY 2019 Plans:*** - Complete demonstration system Manufacturing Readiness Review (MRRs). - Manufacture and assemble demonstration system. - Complete demonstration system Test Readiness Reviews (TRRs). - Integrate and test demonstration system. - Complete demonstration system Pre-Ship Review (PSR). ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects completion of pathfinder system and demonstration.	33.500	59.000	42.000
Title: Hallmark	27.000	29.000	10.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Hallmark program seeks to demonstrate a space Battle Management Command and Control (BMC2) capability to provide U.S. senior leadership the tools needed to effectively manage space assets in real time. The program will develop command and control decision support tools for full-spectrum space operations, management, and control from peace to potential conflict. Hallmark will demonstrate the ability to increase space threat awareness via use of multi-data fusion and timely sensor tasking. The program will also improve the ability to protect against threats by using modeling and simulation tools to develop courses of action for both natural events and adversary actions. The program will employ comprehension and visualization techniques to increase commander and operator awareness thereby transforming information to knowledge and effectively communicating and facilitating time-critical decision making. The anticipated transition partner is the Air Force. ***FY 2018 Plans:*** - Integrate cognitive evaluations into tool development. - Standardize evaluation methodology. - Demonstrate and document integrated tools, algorithms, and data schemes. - Evaluate integrated tools to show effectiveness with respect to enhanced decision timeliness and quality. - Allocate tool development for Phase II. - Conduct quarterly integration cycles with complete feedback loop of cognitive evaluations. - Release ontology for community feedback. ***FY 2019 Plans:*** - Release Hallmark software development kit including Hallmark in-a-box for remote development environment. - Transition activity for sustainment of ontology and data model continuous evolution, and for sustainment of BMC2 tool development environment. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion and transition.			
Title: Robotic Servicing of Geosynchronous Satellites (RSGS)	53.643	79.250	108.671
Description: A large number of national security and commercial space systems operate at geosynchronous earth orbit (GEO), providing persistence and enabling ground station antennas to point in a fixed direction. Technologies for servicing of GEO spacecraft would involve a mix of highly automated and remotely operated (from Earth) robotic systems. The Robotic Servicing of Geosynchronous Satellites (RSGS) program seeks to establish the capability to acquire robotic services in GEO suitable for a variety of potential servicing tasks, in full collaboration and cooperation with existing satellite owners and national security space operators, and with sufficient propellant for several years of follow-on capability. Key RSGS challenges include robotic tool/end effector requirements, efficient orbital maneuvering of a servicing vehicle, robotic arm systems, automation of certain spacecraft operations, and development of the infrastructure for coordinated control between the servicer and client spacecraft operations			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
teams. The anticipated transition is to a commercial partner who will provide the satellite to carry the robotic payload and who will operate the robotic servicer. To support the development of a broadly accepted satellite servicing capability, DARPA is using the consortium for execution of rendezvous and servicing operations (CONFERS) approach to bring together experts from the private sector and Government to develop and publish non-binding, consensus-based standards for safe operational approaches. ***FY 2018 Plans:*** - Begin ground segment specification. - Continue development of comprehensive test plan for robotics and for integrated system. - Complete build and test of first flight robotic arm and tool changer. - Complete development of algorithms for automated on-orbit operations. - Complete final design of servicer satellite with commercial partner and provide technical assistance during fabrication. - Continue flight software coding and testing. - Continue development of operator workstations. - Conduct CONFERS first general assembly and open forum. - Publish first draft of consensus on-orbit safety standards through a qualified standards development organization. ***FY 2019 Plans:*** - Begin integration of robotic payload. - Complete build and test of second robotic arm and tool changer. - Fabricate robotic operations test bed. - Complete build of flight units of robotic tools and tool holders. - Begin preparations for launch with Air Force Space Test Program. - Complete build of rendezvous and proximity operations sensors. - Complete payload structures fabrication. - Test final build of flight software. - Convene CONFERS second general assembly and open forum. - Publish revised on-orbit safety standards inclusive of lessons learned from on-going commercial and government activity. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects integration of robotic payload and fabrication of multiple items including robotic arm and tool changer, testbed, flight ready tools and tool holders, sensors, payload structures, and flight software.			
Title: Blackjack* ***Description:*** *Formerly Blue Check	-	10.000	15.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The Blackjack program will develop space technologies demonstrating a proliferated smallsat constellation capability in Low Earth Orbit (LEO). Capabilities demonstrated will provide constant custody of very large numbers of concurrent targets; target identification, tracking, and characterization; architectural resilience via massive proliferation; and rapid on-orbit technology refresh and experimentation. Blackjack will leverage commercial industry plans to build constellations in LEO to provide global commercial broadband internet service. Key efforts include low size, weight, power, and cost (SWaP-C) multi-modality smallsat sensor payloads, algorithms for autonomous payload and architecture command and control, algorithms for satellite on-board processing and data fusion, and advanced manufacturing for military payload mass production. The anticipated transition partner is the Air Force. ***FY 2018 Plans:*** - Identify government operations, mission, and transition partners. - Conduct system architecture and trade studies. - Develop design reference missions and determine architecture level requirements. - Identify high technical risks areas and develop risk reduction plans. - Develop satellite bus and payload interface definition documents. ***FY 2019 Plans:*** - Complete demonstration system Conceptual Design Review (CoDR). - Complete Preliminary Design Review (PDR) for risk reduction efforts. - Begin development of commoditized satellite bus. - Begin development of demonstration sensor payloads. - Begin ground and on-orbit experimentation with commercial industry satellite constellations for risk reduction efforts. - Begin development of autonomous control element. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects transition from initial studies to risk reduction, payload development, and initial experimentation.			
Title: Advanced Space Technology Concepts	-	2.000	2.000
Description: Studies conducted under this program will examine and evaluate emerging technologies and concepts with the potential to provide substantial improvement in efficiency and effectiveness of operations in space. This includes the degree and scope of potential impact and improvements to military operations, mission utility, and warfighter capability. Studies are also conducted to analyze emerging threats along with possible methods and technologies to counter them. The feasibility of achieving potential improvements, in terms of resources, schedule, and technological risk, is also evaluated. The results from these studies are used, in part, to formulate future programs or refocus ongoing work. Topics of consideration include			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
advanced or novel propulsion systems, novel sensors, advanced lightweight structures, advanced miniature radio frequency (RF) technology, navigation technologies, avionics, structures, advanced communications and on-orbit software environments. ***FY 2018 Plans:*** - Initiate studies of new technologies. ***FY 2019 Plans:*** - Perform studies to evaluate employment of new systems and architectures.			
Title: Planar Imager ***Description:*** The Planar Imager program will develop a low size, weight, and power (SWaP) electro-optical (EO) imager using photonic integrated circuits (PICs) and other novel approaches to replace conventional telescopes for high altitude, long endurance Unmanned Aerial Vehicle (UAV) persistent platforms and space-based EO sensors for Intelligence, Surveillance, and Reconnaissance (ISR). In order to increase resolution, conventional telescopes have to grow in size and weight. The Planar Imager program will eliminate this constraint by using computational interferometric techniques to replace conventional optics with digital processing, providing dramatic improvements in weight and enabling novel form factors for military imaging systems. ***FY 2019 Plans:*** - Develop scaled-up system design of PIC unit. - Integrate detectors directly into PIC design. - Complete program System Requirements Review (SRR). - Begin development of breadboard planar imager laboratory demonstrator. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.	-	-	10.000
Title: Responsive Access for Space Resilience (RASR): DARPA Launch Challenge ***Description:*** Advances in technology, including networking and computing, have significantly increased the utility of small (<300kg) spacecraft that would previously have been of limited military value. For the simultaneous purposes of responsiveness and resiliency, these spacecraft are envisioned to be built on dramatically faster timelines (weeks instead of years) than are executed today. The current practice for space launch generally favors large launch vehicles with complex, one-of-a-kind infrastructure. This architecture has been matched to the large, heavy spacecraft, which compose most of DoD's space architecture today. Small spacecraft, which offer large potential value for resiliency and tactical employment, are typically required to rideshare for access to space which requires programmatic, technical, and schedule entanglement with other programs. The U.S. commercial sector has promising developments for small launch vehicles that are designed for launch on rapid timescales with minimal fixed infrastructure. To incentivize industry to deliver capability that can meet emerging DoD needs for rapid,	-	-	5.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
responsive launch of small payloads, the DARPA Launch Challenge will reward competitors who can demonstrate the ability to launch a payload to orbit with minimal notification time and unknown pre-conditions regarding the payload configuration, required orbit, and launch site. The U.S. Government can make future use of commercial contracting mechanisms for rapid space launch with successful performers. The anticipated transition partners are the Air Force and NASA. ***FY 2019 Plans:*** - Investigation of commercial partnerships for space payloads. - Assess launch site feasibility and facility technical accommodations. - Develop and test multi-launch site compatible downrange telemetry return capabilities. - Create scalable commercial payload packages to support range of launch capabilities. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY2019 increase reflects program initiation.			
Title: Large In-Situ Manufactured Apertures (LIMA) ***Description:*** The Large In-Situ Manufactured Apertures (LIMA) program seeks to study the structural fabrication of a high-performance optical telescopes and radio frequency (RF) antennas attached to a microsatellite. Larger, more powerful and directional than any comparable aperture that could be deployed from a microsatellite platform, LIMA would deliver high-performance imagery, communication and data services to the dismounted warfighter at significantly lower cost while enabling intelligence capability. The program seeks to achieve greater than 50% savings in individual imagery and communications satellite system launch costs and a corresponding increase in launch opportunities due to ride sharing relative to the preferred state of the art solution. ***FY 2018 Plans:*** - Study in-space fabrication process technologies in ground-based trials, including validation of key process elements in flight-like environments. - Prove by analysis that the hosted payload is accommodated without an increase in constellation total launch cost compared to the constellation without the augmented microsatellites. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	-	7.185	-
Title: Space Surveillance Telescope (SST) ***Description:*** The Space Surveillance Telescope (SST) program has developed and demonstrated an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability. A major goal of the SST program, to develop the technology for large curved focal surface array sensors to enable an innovative	6.000	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E *I SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
telescope design combining high detection sensitivity, short focal length, wide field of view, and rapid step-and-settle to provide orders of magnitude improvements in space surveillance has been achieved. This capability enables ground-based detection of un-cued objects in deep space for purposes such as asteroid detection and space defense missions. The SST Australia effort developed advanced algorithms, equipment, and concepts of operation to achieve comparable telescope performance in the more challenging Australian atmosphere. This enhanced capability was demonstrated at White Sands Missile Range, allowing estimates of the performance in Australia to be validated. This program addressed technical challenges which arise from an Australian site, including adaptations to a different telescope environment. The system, algorithms, and concepts of operation transitioned to Air Force Space Command (AFSPC).			
Accomplishments/Planned Programs Subtotals	162.643	247.435	254.671

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	52.990	79.173	111.099	-	111.099	145.159	192.760	207.577	217.629	-	-
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	52.990	79.173	60.399	-	60.399	93.489	140.760	155.577	165.629	-	-
MT-16: *BEYOND SCALING ADVANCED TECHNOLOGIES*	-	0.000	0.000	50.700	-	50.700	51.670	52.000	52.000	52.000	-	-

A. Mission Description and Budget Item Justification

The Advanced Electronics Technologies program element is budgeted in the Advanced Technology Development Budget Activity because it seeks to design and demonstrate state-of-the-art manufacturing and processing technologies for the production of various electronics and microelectronic devices, sensor systems, integrated photonic-electronic components that have military applications and potential commercial utility. Introduction of advanced product design capability and flexible, scalable manufacturing techniques will enable the commercial sector to rapidly and cost-effectively satisfy military requirements.

The Mixed Technology Integration project funds the advanced development and demonstration of selected basic and applied electronics research programs. Examples of technologies with funded development and demonstration activities include, but are not limited to: (1) self-contained laser weapon systems to protect airborne platforms from emerging surface-to-air missiles; (2) integrated photonic-electronic components for positioning, navigation and timing in GPS-denied environments; (3) flexible, software-defined cameras that enable real-time image analysis of complex scenes to provide more actionable information; and (4) component programs that integrate mixed signal (analog and digital) or mixed semiconductor technology to substantially improve the capability of existing components and/or reduce their size, weight and power. Funding under this project is intended to advance transitioning novel technologies to use, providing advanced components compatible with mid-term and other future warfighting requirements.

The Beyond Scaling Advanced Technologies project is a continuation of DARPA's basic and applied research in this area and will support activities in large scale co-development with leading industry players to enable and accelerate transformative computing interactions with industry. Additionally, funding under this project is intended to secure the design and capture of advanced intellectual property (IP) and architectures, IP sharing and re-use, and limited access to state-of-the-art (SOTA) and state-of-the-practice (SOTP) foundries for microelectronics fabrication runs.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603739E *I ADVANCED ELECTRONICS TECHNOLOGIES*

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	49.807	79.173	81.110	-	81.110
Current President's Budget	52.990	79.173	111.099	-	111.099
Total Adjustments	3.183	0.000	29.989	-	29.989
• 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	3.710	0.000			
• SBIR/STTR Transfer	-0.527	0.000			
• TotalOtherAdjustments	-	-	29.989	-	29.989

Change Summary Explanation

FY 2017: Increase reflects reprogrammings offset by the SBIR/STTR transfer.

FY 2018: N/A

FY 2019: Increase reflects expanded focus in the Beyond Scaling Advanced Technologies Project supporting the Electronics Resurgence Initiative (ERI).

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	Project (Number/Name) MT-15 / *MIXED TECHNOLOGY INTEGRATION*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	52.990	79.173	60.399	-	60.399	93.489	140.760	155.577	165.629	-	-

A. Mission Description and Budget Item Justification

The Mixed Technology Integration project funds the advanced development and demonstration of selected basic and applied electronics research programs. Examples of technologies with funded development and demonstration activities include, but are not limited to: (1) self-contained laser weapon systems to protect airborne platforms from emerging surface-to-air missiles; (2) integrated photonic-electronic components for positioning, navigation and timing in GPS-denied environments; (3) flexible, software-defined cameras that enable real-time image analysis of complex scenes to provide more actionable information; and (4) component programs that integrate mixed signal (analog and digital) or mixed semiconductor technology to substantially improve the capability of existing components and/or reduce their size, weight and power. Funding under this project is intended to advance transitioning novel technologies to use, providing advanced components compatible with mid-term and other future warfighting requirements.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Precise Robust Inertial Guidance for Munitions (PRIGM)	15.200	20.000	13.600
Description: The Precise Robust Inertial Guidance for Munitions (PRIGM) program aims to develop inertial sensor technologies for positioning, navigation, and timing (PNT) in GPS-denied environments. These inertial sensors can provide autonomous PNT information when GPS is unavailable. The program will exploit recent advances in integrating photonic (light-manipulating) components into electronics and in employing microelectromechanical systems (MEMS) as high-performance inertial sensors for use in extreme environments. Whereas conventional MEMS inertial sensors suffer from inaccuracies due to factors such as temperature sensitivity, photonics-based PNT techniques have demonstrated the ability to reject these inaccuracies. PRIGM will focus on two areas: (1) By 2020, it aims to develop and transition a Navigation-Grade Inertial Measurement Unit (NGIMU), a state-of-the-art MEMS device, to DoD platforms; and (2) By 2030, it aims to develop Advanced Inertial MEMS Sensors (AIMS) that can provide gun-hard, high-bandwidth, high dynamic range navigation for GPS-free munitions. These advances should enable navigation applications, such as smart munitions, that require low-cost, size, weight, and power (SWaP) inertial sensors with high bandwidth, precision and shock tolerance. PRIGM will advance state-of-the-art MEMS gyros from TRL-3 devices to a TRL-6 transition platform, eventually enabling the Service Laboratories to perform TRL-7 field demonstrations. The ultimate goal is to develop a complete MEMS-based NGIMU with a mechanical/electronic interface identical to existing DoD-standard tactical-grade MEMS IMUs, providing a drop-in replacement for existing DoD systems. Service laboratories have been actively involved throughout program development and remain engaged to facilitate transition of NGIMU prototypes, which will be delivered at the program conclusion. This program has basic research efforts funded in PE 0601101E, Project ES-01 and applied research efforts funded in PE 0602716E, Project ELT-01.			
FY 2018 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Deliver five MEMS gyroscopes meeting environmental and performance requirements (vibration, shock survivability, operation over temperature). - Deliver five MEMS accelerometers meeting environmental and performance requirements (vibration, shock survivability, operation over temperature). - Commence development of MEMS-based, navigation-grade, integrated IMU meeting program-defined SWaP and performance metrics, excluding environmental requirements and shock survival. ***FY 2019 Plans:*** - Complete development and characterization of MEMS-based, navigation-grade, integrated IMU meeting program-defined SWaP and performance metrics, excluding environmental requirements and shock survival. - Deliver two MEMS-based, navigation-grade, integrated IMU prototypes for government evaluation. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects a transition from development to completion and characterization of IMU prototypes.			
Title: Reconfigurable Imaging (ReImagine) ***Description:*** The Reconfigurable Imaging (ReImagine) program aims to create multi-functional readout integrated circuits (ROICs) that fundamentally change the way camera systems collect, process and relay image information. This is accomplished by adding multifunctional flexibility in the ROIC. Today, most cameras are designed to capture high quality imagery at standard frame rates. These traditional camera architectures collect a single type of data across the full image frame. Specialty cameras can be used to capture different spatial, spectral or temporal data but are rarely deployed because of the cost and complexity of adding imaging subsystems for niche measurements. Although these measurements are typically only desired for specific features or regions of interest (ROIs) in a scene, the cameras collect the specialized data over the full image frame. The ReImagine architecture, conversely, would enable a single, real-time reconfigurable, software-defined camera system with the ability to collect different data in different ROIs. Depending on the need, a ReImagine imager would be able to selectively collect and simultaneously process data from a specific ROI, for example, at a higher resolution (i.e., foveated imaging), at a higher frame rate or with 3-D depth information. The system would interface with virtually any sensor and could therefore be used in any spectral band. By demonstrating more efficient data collection and computation across ROIs, ReImagine ROICs should enable real-time analysis of much more complex scenes and provide more actionable information than has ever been possible. Technologies from this program are intended for transition to the Air Force, Navy and Army. ***FY 2018 Plans:*** - Complete mapping multi-function processing algorithms to the ROIC layer using custom software tools. - Begin development of the 2nd generation (Gen-2) designs. - Complete 3-D integration of the ReImagine Gen-1 multilayer ROIC.	15.790	22.173	24.000

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Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate the application benefits of multifunctional capability through simulation. ***FY 2019 Plans:*** - Continue the fabrication of a ReImagine Phase 1 prototype imager. - Develop a detailed operational description and simulation for the ReImagine Gen-2 multi-functional digital ROIC, mapping applications and demonstrating enhanced operation and capability. - Initiate design and layout of the ROIC interface and focal plane array layers to operate with the Gen-2 multi-functional digital ROIC for enhanced programmable functionality. - Develop a detailed plan for a Gen-2 multi-functional digital ROIC camera prototype. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects minor program repricing.			
Title: Rapid Array Development (RAD)	-	12.000	17.799
Description: The Rapid Array Development (RAD) program seeks to leverage recent developments in flexible and adaptive radio frequency (RF) hardware, access to a larger variety of more powerful computing platforms, and advances in software virtualization to radically change the development and deployment cycle for electromagnetic (EM) arrays. EM arrays, which enable communications, radar and electronic warfare (EW), are currently high performance but slow and costly to create. In contrast, they must evolve rapidly in order to adapt to new modes of operation and changing operating parameters associated with modern military threats. However, the available design and test infrastructure is not flexible enough to support testing and fielding new EM array algorithms across a wide variety of military platforms. Furthermore, EM software and hardware are often developed in separate silos; as a result, implementing new EM applications in hardware tends to require a lengthy and expensive development process with extended cycles of iteration between the two areas. RAD will therefore focus on three core areas: (1) making ultra-flexible testbeds for existing and future EM arrays accessible to the DoD community; (2) reducing the complexity of phased array hardware through high level abstraction; and (3) speeding up EM system development time through hardware/software co-design. In light of changing requirements, the resulting technologies would also enable DoD greater reuse of its available hardware resources while minimizing the need to modify specialized EM systems, leading to improved and simplified upgrade cycles. Technologies developed under the RAD program are planned for transition to the services through a series of demonstrations proving the radically shorter time scale of development. ***FY 2018 Plans:*** - Initiate development of a compute engine to optimize the implementation of EM algorithms on a system of heterogeneous processors. - Initiate development of cloud-based applications to facilitate rapid re-configuration of an array platform without having to modify existing hardware.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Explore use of toolchains and toolsets for programming on heterogeneous computing systems. - Explore new models of machine learning and supervisory controls to manage complex allocation of processing resources. ***FY 2019 Plans:*** - Develop a flexible array testbed that will be the common hardware platform for an applications development environment. - Develop a processing platform capable of executing EM algorithms, array configuration, data flow and end-user interactions. - Continue development of cloud-based applications to facilitate rapid re-configuration of an array platform without having to modify existing hardware. - Initiate plans for a testbed installation at a military base or radar test range. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects the shift from exploring and initiating development to developing RAD software and the testbed environment.			
Title: Millimeter Wave Digital Arrays (MIDAS) *	-	10.000	-
Description: *formerly Radio Frequency Collaborative Unmanned Distributed System (RF CLOUDS) The Millimeter Wave Digital Arrays (MIDAS) program will develop a common millimeter wave phased-array tile that is scalable to large arrays to provide wideband frequency agility from 18-50 GHz with element-level digital beamforming. Millimeter wave systems are used today to achieve physical security through the use of narrow antenna beams in a small form-factor. We see this applied to satellite communications and tactical line-of-sight communications such as in the F-22 and F-35. One of the challenges of using directional communications in mobile applications is the problem of knowing where to point the antenna when both platforms are mobile. This can be solved with digital beamforming to enable a mobile platform to listen in all directions with many antenna beams to facilitate neighbor discovery and when transmitting, multiple beams can be used to communicate with several neighbors simultaneously. This capability will increase the network throughput and robustness that will be tolerant to unexpected outages. To achieve these goals, the program will develop a common digital phased array tile that can be used to build large arrays from this common block. The program will be executed in two primary technical areas. First, advanced complementary metal oxide semiconductor (CMOS) will be used to develop the core transceiver elements at a size and power consumption that is required to fit in the small size required by current millimeter wave systems. Second, a combination of advanced packaging and high-performance semiconductors will be used to build the wideband antenna and front-end amplifiers necessary to make a complete system. ***FY 2018 Plans:*** - Begin preliminary design review.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Begin development of a low-power, 16-element, element-level digital phased array at millimeter wave frequencies in advanced CMOS. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The decrease in FY 2019 reflects the program moving to Project MT-16.			
Title: Efficient Ultra-Compact Laser-Integrated Diodes (EUCLID) ***Description:*** The Efficient Ultra-Compact Laser-Integrated Diodes (EUCLID) program aims to significantly reduce the size of laser diode pump modules (DPMs) while increasing their electrical-to-optical efficiency. DPMs are a critical component of fiber-laser array weapons systems, which combine light from many lower-power lasers to engage targets at tactically-relevant distances. Commercial DPMs, which cater to the laser manufacturing industry, feature large cooling systems and are too cumbersome for integration into many small DoD platforms. EUCLID plans to leverage advances in thermal management components to design, build, test, and demonstrate densely packageable, prototype DPMs that are less than half the size of their commercial counterparts. The program will also pursue improved optical components that can more efficiently focus light from individual laser diodes. The resulting EUCLID DPMs are intended to be available for procurement and integration into ultra-low size, weight, and power fiber-laser array weapons systems, enabling integration into a variety of Air Force, Navy, Army, and Missile Defense Agency platforms. ***FY 2018 Plans:*** - Complete critical design of a >650 Watt, >60% efficiency DPM with less than 0.31 cm3/Watt and 0.31 grams/Watt, including integrated thermal management and improved optical designs. - Model and simulate thermal management systems to demonstrate laser diode operation at a designated temperature, given appropriate coolant temperature, flow rate, and pressure drop values. - Model optical designs to demonstrate that coupling efficiency from the laser diode bars to the delivery fiber is within the overall system's electrical-to-optical efficiency budget. ***FY 2019 Plans:*** - Build and test prototype DPMs which produce >4 kW of optical power and >58% efficiency and are suitable for powering a coherently combinable fiber laser amplifier assembly. - Generate detailed designs of a compact, packaged 4 kW diode pump assembly based on the prototype DPMs.	-	5.000	5.000
Title: Endurance ***Description:*** The Endurance program aims to develop laser technology to protect airborne platforms from emerging and legacy electro-optical/infrared (EO/IR) guided surface-to-air missiles. Endurance is planned to have an open architecture, granting the flexibility to integrate different subsystems with varying capabilities. Endurance is an early application of technology developed	16.000	10.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
through DARPA's Excalibur program and is planned to transition to the Services. The advanced technology component of the program will focus on developing and field testing various subsystems for laser beam generation, command and control, threat missile warning, target acquisition and tracking, beam control, energy storage and delivery, and thermal management. It will also develop subsystem interfaces and integrate the components into a packaged system for field testing. Technologies from this program are intended for transition to the Services. ***FY 2018 Plans:*** - Assess brassboard system performance in live-fire testing. - Perform environmental testing to assess performance under stressing vibrational and temperature conditions. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion and planned transition to the Services.			
Title: FLASH - Scaling Fiber Arrays at Near Perfect Beam Quality ***Description:*** The FLASH program demonstrated an ultra-low-size, weight, and power (SWaP) high energy laser system suitable for integration onto a range of military platforms, including unmanned aerial vehicles (UAVs) and 4th and 5th generation aircraft. With its modular, scalable architecture, future systems could be built with output power levels in the hundreds of kilowatts, enabling a broad set of offensive mission capabilities, many of which are not possible with current technology. To accomplish its program goals, FLASH pursued two major thrusts. First, FLASH greatly reduced the size and weight of high-power fiber laser amplifiers, increased their power efficiency and improve their resistance to shock, vibration and acoustic stresses found on military platforms. Second, FLASH fabricated an array of these amplifiers and integrated them into a transportable system with advanced battery power, thermal management and coherent-beam combination sub-systems. Technologies from this program are intended for transition to the Air Force, Navy, Army and Missile Defense Agency.	3.500	-	-
Title: Diverse & Accessible Heterogeneous Integration (DAHI) ***Description:*** The Diverse Accessible Heterogeneous Integration (DAHI) program developed the design and manufacturing capabilities required to seamlessly integrate various semiconductors, microelectromechanical systems, photonic (light-manipulating) devices and thermal management structures into true systems-on-a-chip (SOC). This capability enabled dramatic size, weight and volume reductions and higher performance for DoD electronic warfare, communications and radar systems. Historically, chip designers have had to decide between the availability, development and low cost of silicon circuits or the high performance of compound semiconductor (CS) materials. DAHI, however, built on previous DARPA and commercial efforts, which demonstrated that heterogeneously integrating CS and silicon can yield significant performance improvements over silicon or CS alone. DAHI's advanced technology development effort focused on establishing a technologically mature manufacturing path for integrating a wide array of materials and devices, including CS, on a common substrate. Relevant	2.500	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
manufacturing processes are made available to a wide variety of designers from the DoD laboratories, federally funded research and development centers, academia and industry. DAHI supported demonstrating increasingly complex circuits that leverage heterogeneous integration. DAHI technologies are intended for transition to national security and semiconductor manufacturing partners. This program has applied research efforts funded in PE 0602716E, Project ELT-01.			
Accomplishments/Planned Programs Subtotals	52.990	79.173	60.399

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	Project (Number/Name) MT-16 / *BEYOND SCALING ADVANCED TECHNOLOGIES*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
MT-16: *BEYOND SCALING ADVANCED TECHNOLOGIES*	-	0.000	0.000	50.700	-	50.700	51.670	52.000	52.000	52.000	-	-

A. Mission Description and Budget Item Justification

The Beyond Scaling Advanced Technologies Project is a continuation of DARPA's basic and applied research in this area and will support activities in large scale co-development with leading industry players to enable and accelerate transformative computing interactions with industry. Additionally, funding under this project is intended to secure the design and capture of advanced intellectual property (IP) and architectures, IP sharing and re-use, and limited access to state-of-the-art (SOTA) and state-of-the-practice (SOTP) foundries for microelectronics fabrication runs.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Beyond Scaling - Access	-	-	30.000
Description: The Beyond Scaling - Access program will demonstrate the design and fabrication of advanced electronics through collaborations with leading industry players. Although the United States has led the development of advanced electronics since its inception and is home to three of the five leading-edge foundries, recent investments by foreign competitors are threatening this leadership. Additionally, the fabrication cost of next generation microelectronics has increased at an alarming rate. While the commercial sector is able to spread these costs over a large volume of products, the low volumes used by the DoD has led to a cost barrier in meeting its future technology needs. In some cases, the inability to place orders in volume has created a lack of access to advanced technology nodes entirely. To address this, the DoD must participate in more industry partnerships that not only leverage investments in the commercial industry but also provide access to SOTA facilities in the U.S. This program will build on existing relationships and forge forward-looking collaborations among the commercial electronics community, defense industrial base, university researchers, and the DoD. Activities include securing advanced IP and electronics architectures, IP sharing and re-use, and limited access to SOTA and SOTP foundries for microelectronics fabrication runs. ***FY 2019 Plans:*** - Identify and secure access to SOTA commercial IP for use in DoD designs. - Demonstrate IP sharing and reuse of IP across various DoD and commercial designs. - Establish SOTA and SOTP microelectronics fabrication runs for DoD designs at leading-edge commercial foundries. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects program initiation.			
Title: Millimeter Wave Digital Arrays (MIDAS)* ***Description:*** *Formerly Radio Frequency Collaborative Unmanned Distributed System (RF CLOUDS)	-	-	20.700

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-16 / *BEYOND SCALING ADVANCED TECHNOLOGIES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The Millimeter Wave Digital Arrays (MIDAS) program will develop a common millimeter wave phased-array tile that is scalable to large arrays to provide wideband frequency agility from 18-50 GHz with element-level digital beamforming. Millimeter wave systems are used today to achieve physical security through the use of narrow antenna beams in a small form-factor. We see this applied to satellite communications and tactical line-of-sight communications such as in the F-22 and F-35. One of the challenges of using directional communications in mobile applications is the problem of knowing where to point the antenna when both platforms are mobile. This can be solved with digital beamforming to enable a mobile platform to listen in all directions with many antenna beams to facilitate neighbor discovery and when transmitting, multiple beams can be used to communicate with several neighbors simultaneously. This capability will increase the network throughput and robustness that will be tolerant to unexpected outages. To achieve these goals, the program will develop a common digital phased array tile that can be used to build large arrays from this common block. The program will be executed in two primary technical areas. First, advanced complementary metal oxide semiconductor (CMOS) will be used to develop the core transceiver elements at a size and power consumption that is required to fit in the small size required by current millimeter wave systems. Second, a combination of advanced packaging and high-performance semiconductors will be used to build the wideband antenna and front-end amplifiers necessary to make a complete system. Technologies from this program are intended for transition to the Services. ***FY 2019 Plans:*** - Demonstrate a low-power, 16-element, element-level digital phased array at millimeter wave frequencies in advanced CMOS. - Demonstrate a wideband and efficient power amplifier technology co-packaged with a wideband antenna. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects the program moving from Project MT-15.			
Accomplishments/Planned Programs Subtotals	-	-	50.700

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	123.934	106.787	185.984	-	185.984	158.245	160.092	224.084	222.153	-	-
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	62.677	55.928	106.316	-	106.316	89.675	108.092	188.584	214.153	-	-
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	61.257	50.859	79.668	-	79.668	68.570	52.000	35.500	8.000	-	-

A. Mission Description and Budget Item Justification

The Command, Control and Communications Systems program element is budgeted in the Advanced Technology Development Budget Activity because its purpose is to demonstrate and evaluate advanced information systems research and development concepts.

The success of military operations depends on timely, reliable, secure, and synchronized dissemination of command and control and relevant situational awareness information to every military echelon. While wired communications and networks are fairly well developed, providing assured high-bandwidth mobile wireless capabilities that match or exceed commercial wired infrastructure is needed to meet the demands of military users. The goal of the Information Integration Systems project is to develop and demonstrate technologies that will provide effective communications to U.S. forces. Approaches to this goal include developing technologies in these areas:
- High-Capacity Links technologies - enables greater back-haul capability.
- Advanced Networking technologies - supports resilience, adaptability, and scalability.
- Low Probability of Detection and Anti-Jam (LPD/AJ) technologies - provides assured communications in very high-threat environments.
- Novel Radio Frequency and Spectral Sensing (RF/SS) - supports efficient spectrum management in congested environments and detection of electromagnetic threats.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	155.081	106.787	137.904	-	137.904
Current President's Budget	123.934	106.787	185.984	-	185.984
Total Adjustments	-31.147	0.000	48.080	-	48.080
• Congressional General Reductions	-9.375	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	-8.905	0.000			
• SBIR/STTR Transfer	-12.867	0.000			
• TotalOtherAdjustments	-	-	48.080	-	48.080

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603760E *I COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*

Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction, reprogrammings and the SBIR/STTR transfer.

FY 2018: N/A

FY 2019: Increase reflects initiation of the Network Universal Persistence, Protected Forward Communications programs, and classified program expansion.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	Project (Number/Name) CCC-02 / *INFORMATION INTEGRATION SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	62.677	55.928	106.316	-	106.316	89.675	108.092	188.584	214.153	-	-

A. Mission Description and Budget Item Justification

The success of military operations depends on timely, reliable, secure, and synchronized dissemination of command and control and relevant situational awareness information to every military echelon. While wired communications and networks are fairly well developed, providing assured high-bandwidth mobile wireless capabilities that match or exceed commercial wired infrastructure is needed to meet the demands of military users. The goal of the Information Integration Systems project is to develop and demonstrate technologies that will provide effective communications to U.S. forces. Approaches to this goal include developing technologies in these areas:

- High-Capacity Links technologies - enables greater back-haul capability.
- Advanced Networking technologies - supports resilience, adaptability, and scalability.
- Low Probability of Detection and Anti-Jam (LPD/AJ) technologies - provides assured communications in very high-threat environments.
- Novel Radio Frequency and Spectral Sensing (RF/SS) - supports efficient spectrum management in congested environments and detection of electromagnetic threats.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE)	7.000	14.042	28.996
Description: The goal of the Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE) program is to develop innovative networking and information sharing approaches that enable U.S. and coalition forces to effectively and efficiently coordinate tactical operations by eliminating today's prohibitive cost and security barriers. Building upon the Spectrum Efficiency and Access program, which is budgeted in this PE/Project, and research into the use of commercial systems and infrastructure to support military operations, SHARE provides new opportunities for U.S. and coalition forces to gain and maintain a tactical advantage on the battlefield. Coordination includes providing all the information required to enable the command and control necessary to plan and execute operations in all phases of warfare. Technology from this program will be made available to the Services and DoD Agencies that work with coalition partners. ***FY 2018 Plans:*** - Perform laboratory experiments and evaluations of the network software for secure and resilient sharing. - Develop software for commercial handheld devices to support sharing and fusion of information from various data sources at multiple security levels. - Develop the architecture and software for automated configuration of multiple security levels across coalition networks. - Develop software to enable integration of commercial large data systems with military infrastructure.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop technologies allowing future military networks to work with badly degraded radio links. ***FY 2019 Plans:*** - Integrate and test multi-level, handheld software and new networking architecture supporting the sharing of information at multiple security levels. - Conduct controlled, limited field experimentation on handheld devices demonstrating multi-level secure information sharing and network security. - Develop and update as required, based on laboratory testing and experimentation, automated network configuration software ensuring compatibility with handheld and network approach. - Conduct system security assessment and compliance with overall program sharing and security objectives. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects additional requirements to integrate, test, and demonstrate handheld and networking software.			
Title: Dynamic Network Adaptation for Mission Optimization (DyNAMO)	19.154	17.698	17.965
Description: Wireless networks have evolved into complex systems having many configurable parameters/features, including link data rates, power settings, inter-network gateways, and security associations. The optimal settings for these features vary greatly depending on the mission for which the network is deployed and the environment in which it is operating. Currently, the majority of these features are optimized off-line for specific scenarios and assumptions and are pre-set before use in a mission. There is no capability for the settings to adapt if the actual mission or environment differs from the original assumptions used to configure the network. The problem is exacerbated in scenarios in which intelligent adversaries can affect the topology and operation of the network unpredictably and on short timescales. Furthermore, future operations will include multiple, different radios interconnected on the same platform, and those existing networks lack a common standard for interoperability. The Dynamic Network Adaptation for Mission Optimization (DyNAMO) program will develop software that addresses the incompatibilities preventing information sharing across independent airborne networks and develop new approaches to configure and control networks and networks of networks for operation in dynamic and contested environments. The program will address optimization within legacy and future military networks, interactions between networks, and availability of necessary network services to support mission success. Technologies developed under this program will transition to the Services. ***FY 2018 Plans:*** - Continue development and integrate initial instantiation of real-time optimization algorithms in radio hardware. - Continue development and integration of mission-based network architecture control and information delivery mechanisms. - Conduct hardware-in-the-loop test of integrated system with instantiations of inter-network coordination, mission-based control, and real-time optimization.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Conduct system-level emulation test of advanced network infrastructure with final instantiation of inter-network coordination, mission-based control, and real-time optimization. ***FY 2019 Plans:*** - Integrate final instantiation of inter-network coordination, mission-based control, and real-time optimization algorithms in radio hardware. - Conduct ground test of integrated system. - Conduct field test of integrated system with instantiations of inter-network coordination, mission-based control, and real-time optimization. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects minor program repricing.			
Title: Spectrum Efficiency and Access ***Description:*** The Federal Government is working to transition large swaths of spectrum (up to 500 MHz) from Federal (DoD is the primary contributor) to civilian use for broadband telecommunications. The DoD will need more highly integrated and networked data/sensor capacity over the next decades and will therefore need new technology that requires less spectrum to operate. The objective of the Spectrum Efficiency and Access program is to investigate improvements in spectral reuse, such as spectrum sharing of sensor/radar bands. The program will leverage technical trends in cooperative sharing to exploit radar anti-jam and interference mitigation technologies that could enable spectrum sharing by allowing overlay of communications within the same spectral footprint. The approach will include exploring real-time control data links between radars and communications systems, and developing the advanced waveforms and components to enable radars and communication networks to operate in close proximity. The ultimate goal is to turn the DoD spectrum loss into a net gain of up to hundreds of MHz in capacity. Technology from this program will be made available to the Navy, Army, and Missile Defense Agency (MDA). ***FY 2018 Plans:*** - Develop advanced radio frequency (RF) waveform and associated signal processing technology. - Implement transition plans with identified Navy, Army, and MDA stakeholders. ***FY 2019 Plans:*** - Demonstrate spectrum maneuver command and control concepts. - Commence design of a system capable of dynamically controlling radio frequency signatures while maintaining high accuracy target tracking. ***FY 2018 to FY 2019 Increase/Decrease Statement:***	9.500	8.589	8.987

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 increase reflects minor program repricing.			
Title: 100 Gb/s RF Backbone	8.342	5.718	6.287
Description: The proliferation of video, voice, chat, and other important data-streams on the battlefield is driving a need for higher capacity, reliable, assured, and all-weather communications that are deployable on a wide range of air, ground, and maritime platforms. The goal of this High-Capacity Links technologies program is to demonstrate a 100 Gigabit-per-second (Gb/s) radio frequency (RF) backbone that will meet the anticipated mid-term (within 3-10 years) wireless networking requirements of deployed military forces. DARPA's hybrid Free Space Optical RF Communications Adjunct (ORCA) system has broken the 10 Gb/s wireless network boundary using free-space optical links, but all-weather Ku band components are currently limited to much less than 1Gb/s capacity. Furthermore, the hybrid optical/RF system exhibits size, weight, and power (SWaP) consumption characteristics that preclude deployment on many SWaP-limited platforms. Moving to a millimeter-wave (mmW) solution will provide high capacity and all-weather resiliency, but presents technical challenges that include the generation of higher-order waveforms (beyond common data link), efficient power transmission, high-speed routing, and low-noise receivers. This program seeks to develop the constituent subsystems (waveform generation, efficient power amplifiers, and receivers) and spatial multiplexing architectures to construct an all-weather mmW 100 Gb/s backbone at half the SWaP consumption of the current ORCA system. The 100 Gb/s RF Backbone program is intended for transition to multiple Services. ***FY 2018 Plans:*** - Integrate prototype onto test aircraft and conduct air-to-ground testing. - Complete air-to-ground testing and conduct flight demonstration to Services. - Make technologies from the 100 Gb/s RF Backbone system available for transition to the Services, and specifically to the Air Force Common Data Link project. - Develop applications of advanced modulation and spatial multiplexing to make data links more resilient to threats in addition to providing high data rate. ***FY 2019 Plans:*** - Conduct joint flight demonstrations with Services. - Engage in targeted design activity for specific applications. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects initiation of activity in support of Service transition.			
Title: Geospatial Cloud Analytics (GCA)	-	8.722	19.993
Description: The Geospatial Cloud Analytics (GCA) program will develop technology to access and analyze global scale, multimodal geospatial data and pilot an analytics-as-a-service business model. Exploiting multiple sources and modalities at			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
a global scale requires the development of technologies and systems that provide common access points to commercial data, computational power to preprocess data and make it exploitable by analytical tools, and new models supporting sensing and analytics as services including sharing of tools and results between individuals and consortiums. GCA creates a capability for near real time monitoring of global events and change detection across various environments and warfighting domains, building upon the Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE) coalition warfighter information sharing program, also in this Program Element. By exploiting the vast amounts of geospatial information from new commercial satellite constellations and other sources, GCA will create the technology foundations needed to provide global awareness of gray-zone activities. It will do so by augmenting commercial capabilities with defense assets, not vice versa, and thereby improve speed, agility, and scalability. Technology from this program will transition to the Services and DoD Agencies to meet their needs for global situational awareness. ***FY 2018 Plans:*** - Analyze and evaluate potential platforms and algorithms. - Design, prototype, and experiment with software infrastructure to use as a tool to exploit multiple sources and modalities. ***FY 2019 Plans:*** - Analyze computational architectures and frameworks for GCA analytics services at global scale. - Demonstrate the ability of the software infrastructure to support global scale analytics on relevant problem sets. - Demonstrate gray-zone indicators and warnings for high-impact global events such as droughts, crop failures, and illegal fishing. - Experiment with approaches for offering analytics services for use by DoD users and others. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects scale up and demonstration of the GCA infrastructure and analytics.			
Title: Network Universal Persistence (Network UP) ***Description:*** Current radios send network control information and data using the same wireless link. This produces a common failure mode when that wireless link degrades. In many of today's military wireless networks, even brief wireless link outages create a loss of network connectivity that can take more than two minutes to recover once the wireless link is re-established. During these network outages, data transmission is not possible. Building on technologies explored in the Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE) program, also in this PE, the Network UP program will develop and demonstrate radio technology that maintains network reliability through periods of frequent signal degradation that routinely occur in military operational environments. Isolation of critical control channel information in a separate, robust wireless link will allow creation of a protected control channel that can maintain network reliability even when the data channel is lost. The Network UP program will develop technology and a prototype system that enables military wireless networks to send data over dynamic, unstable wireless links. The program will develop approaches to separate the control and data planes across different wireless	-	-	11.495

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
links and design and implement mechanisms to maintain synchronization across those separate links. Technologies developed under this program will transition to the Services. ***FY 2019 Plans:*** - Initiate design of a radio architecture and supporting technology that implement separate control and data channels. - Initiate design of network architectures and technologies that enable creation of a network with physically separated control and data links. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.			
Title: Protected Forward Communications (PFC) ***Description:*** The collaborative application of combat power in ground tactical operations demands reliable exchange of rich information and precise coordination of actions across various echelons. These operations take place over three critical conversations: (1) to coordinate the actions of a local group, (2) to coordinate group and airborne assets, and (3) to interact with rear echelon command. The communication links over which these three conversations take place are at risk from jamming and geolocation operations conducted with increasingly sophisticated exploitation and denial technology employed by our adversaries. This problem is compounded by demands for ever-increasing capacity of these links. The Protected Forward Communications (PFC) program will build on technical advances in resilient, efficient, and aware communications technology to design a single communication system to protect all three conversations from jamming and geolocation. PFC builds on technology developed in the Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE) program, also in this Program Element. PFC is generally applicable to small unit operations and is particularly relevant to the close air support (CAS) function typically executed by the Joint Terminal Attack Controller (JTAC) or Forward Air Controller (FAC). The PFC program will transition to the Services. ***FY 2019 Plans:*** - Initiate PFC conceptual development. - Start algorithm design for implementation and control of all three communication techniques. - Begin concept validation through modeling and simulation. - Establish readiness of constituent link technologies for all three communication techniques. - Conduct simulation and modeling of systems in representative operating environments to assess resistance to geolocation and jamming. ***FY 2018 to FY 2019 Increase/Decrease Statement:***	-	-	12.593

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 increase reflects program initiation.			
Title: Communication in Contested Environments (C2E)	8.463	1.159	-
Description: The Communication in Contested Environments (C2E) program will seek to address communications problems anticipated in networked airborne systems in the mid-21st century. Expected growth in sensor systems, unmanned systems, and internetworked weapons systems will strain the size of networks that our current communications technology can support in the contested environment. As adversary capabilities advance, the DoD will need new techniques to quickly and efficiently accommodate better networking and improved communications capabilities, specifically communications systems with higher capacity, lower latency, greater jamming resistance, and reduced detectability. As part of Advanced Networking technologies efforts, the C2E program addresses these needs with a three-pronged approach: first, to develop heterogeneous networking capabilities and advanced communication technology for airborne systems. Low Probability of Detection (LPD), Anti-Jam (AJ), low latency, and high capacity communication protocols will be developed. Second, to create a government controlled and maintained reference architecture for communications systems that draws from commercial communication architectures. The defense contractor community can build specific communications systems based upon this reference architecture. Finally, C2E will create a government controlled development environment to allow rapid refresh of communications technology and allow third party native application and waveform developers to contribute their own communications technologies. Technologies from this program are planned to transition to the Services. ***FY 2018 Plans:*** - Complete integration and testing of the Ruggedized Flight System radio. - Demonstrate airborne tactical network waveform interoperability on the C2E Ruggedized Flight System radio. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Title: Advanced RF Mapping	7.218	-	-
Description: One of the key advantages on the battlefield is the ability to actively sense and manipulate the radio frequency (RF) environment, enabling reliable and assured communications, as well as effectively mapping and manipulating the adversary's communications in ways that defy their situational awareness, understanding, or response. Current approaches are emitter-based, with the signal processing techniques focused on array and time-based processing for each emitter. As the RF environment becomes more complex and cluttered, the number of collection assets and the required level of signal processing inhibits our capability to pervasively sense and manipulate at the precision (time, frequency, and space) required for effective action. To address these Radio Frequency and Spectral Sensing (RF/SS) challenges, the Advanced RF Mapping program developed and demonstrated new concepts for sensing and manipulating the RF environment based on distributed rather than centralized collection. This approach took advantage of the proliferation of RF devices, such as radios and cell phones, on the			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
battlefield. To leverage these existing devices effectively, the program developed new algorithms that map the RF environment with minimal communication load between devices. The Advanced RF Mapping program also developed approaches to exploit our precise knowledge of the RF environment and the distributed proximity of RF devices to provide reliable and assured communications for our warfighter as well as to infiltrate or negate our adversaries' communications networks. The Advanced RF Mapping program enabled both offensive and defensive operations in complex RF environments. Advanced RF Mapping technology transitioned to the Services.			
Title: Wireless Network Defense ***Description:*** A highly networked and enabled force increases efficiency, effectiveness, and safety by making relevant information available when it is needed and at the appropriate location (person/platform/system). Accomplishing this depends on providing reliable wireless communications to all U.S. forces, platforms, and devices in all phases of conflict. As part of the Advanced Networks technologies effort, the Wireless Network Defense program increased wireless network capacity and reliability for tactical users, with the ultimate vision of making high quality data services pervasive throughout the DoD. The primary focus was mitigation of advanced threats particular to the security of wireless networks. The program leveraged the capabilities of the dynamic network to identify sources of misinformation, whether malicious or due to poor configuration, across the functional components of the complex system, and mitigated the corresponding effects. Technologies developed under this program transitioned to the Services.	3.000	-	-
Accomplishments/Planned Programs Subtotals	62.677	55.928	106.316

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	Project (Number/Name) CCC-06 / *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	61.257	50.859	79.668	-	79.668	68.570	52.000	35.500	8.000	-	-

A. Mission Description and Budget Item Justification

This project funds classified DARPA programs that are reported in accordance with Title 10, United States Code, Section 119(a)(1) in the Special Access Program Annual Report to Congress.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Classified DARPA Program	61.257	50.859	79.668
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2018 Plans:*** Details will be provided under separate cover. ***FY 2019 Plans:*** Details will be provided under separate cover. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	61.257	50.859	79.668

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Details will be provided under separate cover.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	417.826	439.386	438.569	-	438.569	451.035	417.272	393.145	354.315	-	-
NET-01: *JOINT WARFARE SYSTEMS*	-	54.177	67.114	72.402	-	72.402	120.342	161.307	169.622	176.992	-	-
NET-02: *MARITIME SYSTEMS*	-	135.967	138.112	130.511	-	130.511	126.643	106.465	140.323	147.323	-	-
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	227.682	234.160	235.656	-	235.656	204.050	149.500	83.200	30.000	-	-

A. Mission Description and Budget Item Justification

The Network-Centric Warfare Technology program element is budgeted in the Advanced Technology Development budget activity because it addresses high payoff opportunities to develop and rapidly mature advanced technologies and systems required for today's network-centric warfare concepts. It is imperative for the future of the U.S. forces to operate flawlessly with each other, regardless of which services and systems are involved in any particular mission. The overarching goal of this program element is to enable technologies at all levels, regardless of service component, to operate as one system.

The objective of the Joint Warfare Systems project is to create enabling technologies for seamless joint operations, from strategic planning to tactical and urban operations. Joint Warfare Systems leverage current and emerging network, robotic, and information technology and provide next generation U.S. forces with greatly expanded capability, lethality, and rapid responsiveness. Critical issues facing this project are: (1) U.S. opponents utilizing systems that are flexible, robust, and difficult to neutralize; and (2) U.S. doctrine that limits the use of firepower to lessen the impact of operations on noncombatants. These problems are magnified in urban and semi-urban areas where combatants and civilians are often collocated, and in peacekeeping operations where combatants and civilians are often indistinguishable. Meeting these challenges places a heavy burden on joint war planning. Understanding opponent networks is essential so that creative options can be developed to counter their strategies. Synchronization of air and ground operations to apply force only where needed and with specific effects is required.

The Maritime Systems project will identify, develop and rapidly mature critical advanced technologies and system concepts for the naval forces' role in today's network centric warfare concept. Improvements in communications between and among submarines, surface ships and naval aircraft have allowed these forces to operate seamlessly with each other and with other Service's network centric systems. Naval forces will play an ever-increasing role in network centric warfare because of their forward deployed nature, their unique capability to operate simultaneously in the air, on the sea and under the sea and their versatile ability to provide both rapid strike and project-sustained force. The technologies developed under this project will capitalize on these attributes, improve them and enable them to operate with other network centric forces.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603766E *I NETWORK-CENTRIC WARFARE TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	428.894	439.386	420.714	-	420.714
Current President's Budget	417.826	439.386	438.569	-	438.569
Total Adjustments	-11.068	0.000	17.855	-	17.855
• Congressional General Reductions	-9.000	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	6.355	0.000			
• SBIR/STTR Transfer	-8.423	0.000			
• TotalOtherAdjustments	-	-	17.855	-	17.855

Change Summary Explanation

FY 2017: Decrease reflects Congressional reduction and the SBIR/STTR transfer offset by reprogrammings.

FY 2018: N/A

FY 2019: Increase reflects expanded scope in the Systems of Systems-Enhanced Small Units (SESU) and Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS) programs.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	Project (Number/Name) NET-01 / *JOINT WARFARE SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
NET-01: *JOINT WARFARE SYSTEMS*	-	54.177	67.114	72.402	-	72.402	120.342	161.307	169.622	176.992	-	-

A. Mission Description and Budget Item Justification

The objective of the Joint Warfare Systems project is to create enabling technologies for seamless joint operations, from strategic planning to tactical and urban operations. Joint Warfare Systems leverage current and emerging network, robotic, and information technology and provide next generation U.S. forces with greatly increased capability, lethality, and rapid responsiveness. Critical issues facing this project are: (1) U.S. opponents using systems that are flexible, robust, and difficult to neutralize; and (2) U.S. doctrine that limits the use of firepower to lessen the impact of operations on noncombatants. These problems are magnified in urban and semi-urban areas where combatants and civilians are often co-located and in peacekeeping operations where combatants and civilians are often indistinguishable. Meeting these challenges places a heavy burden on joint war planning. Understanding opponent networks is essential so that creative options can be developed to counter their strategies. Synchronization of air and ground operations to apply force only where needed and with specific effects is required. This project supports all levels of the force structure including: (1) the strategic/operational level by generating targeting options against opponents' centers of gravity that have complex networked relationships; (2) the tactical/operational level by managing highly automated forces with tight coupling between air and ground platforms; and (3) the focused tactical level by developing platforms and tools, which acquire targets of opportunity and cue network-based analysis of likely enemy operations thus maximizing the effectiveness of ground forces in stability and support operations.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: System of Systems Integration Technology and Experimentation (SoSITE)	24.212	27.932	26.518
Description: The System of Systems Integration Technology and Experimentation (SoSITE) program seeks to implement an architecture framework capable of assessing and demonstrating potential operational benefits of integrating various system capabilities to improve mission success in contested environments. Such assessments would optimize system-level trades of requirements and architectures to properly leverage an integrated set of system characteristics and capabilities. The demonstration assessment metrics will measure individual and combined system performance to further streamline resource allocation to maximize operational impact. In addition, providing a modeling and simulation (M&S) environment to assess complex systems will enable greater utility of emerging system technologies, since they can be assessed in near-real-world simulations without the real-world costs of testing fully integrated systems. The program will also develop system synthesis and integration technologies that enable rapid assimilation of new and off-the-shelf technologies into the system of systems architecture. These technologies will break down current barriers to entry that new technologies face in system of systems using formal methods, compositional reasoning, and automated design space exploration. Technologies from this program will be transitioned to the Services.			
FY 2018 Plans:			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Secure test articles for mobile target strike flight test experiments: manned and unmanned platforms, and experimental mission systems from DARPA and Service Science and Technology programs. - Demonstrate the capability of new engineering tools to validate system of systems architecture designs prior to live flight experiments. - Demonstrate the capability of formal verification techniques to validate integration of constituent systems into a system of systems prior to live flight experiments. - Conduct experiments of system of systems architectures for mobile target strike missions in live flight integrated with architectures for offensive counter-air, augmented with virtual and constructive simulation of test articles not ready for live flight; analyze experiment outcomes and document accomplishment of risk reduction objectives. - Secure test articles for networked electronic attack flight test experiments manned and unmanned platforms, and experimental mission systems. ***FY 2019 Plans:*** - Secure test articles for flight test experiments for distributed opposed strike and suppression of enemy air defenses on manned and unmanned platforms, and experimental mission systems. - Demonstrate the capability of new engineering tools to validate system of systems architecture designs prior to live flight experiments. - Demonstrate the capability of formal verification techniques to validate integration of constituent systems into a system of systems prior to live flight experiments. - Conduct integration events to digitally characterize sub-systems to enable rapid integration into systems of systems. - Conduct live flight experiments of system of systems architectures for networked electronic attack, distributed opposed strike, and suppression of enemy air defense missions. - Apply Return Oriented Programming methods to enable rapid upgrade and improve portability of both new and legacy aircraft platform software. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects fewer flight experiments.			
Title: Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE)	20.350	17.772	15.475
Description: Currently, Command and Control (C2) of air platforms is a highly centralized process operating largely independently across planning domains (Intelligence, Surveillance, and Reconnaissance (ISR), strike, and spectrum management) and is optimized for a permissive environment. To address the challenges faced in today's increasingly contested environments, the Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE) program will develop tools and models to enable distribution of planning functions across the C2 hierarchy for resilience (e.g., loss of communications) while synchronizing strike, ISR, and spectrum planning to maximize the contribution of all assets through			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
increased utilization and exploitation of synergies. The program will develop tools supporting a mixed initiative planning approach, maximizing automation according to operator's choice, and enabling human-in-the-loop intervention and modification, as well as tactical decision aids for maritime commanders and planners to build and assess courses of action (COAs) for fleet and ship movements and the employment of counter-Intelligence, Surveillance, and Reconnaissance (ISR) techniques. During execution, the tools will provide lifecycle tracking of targeting and information needs and support assessment of progress towards achieving the commander's intent. The tools will dynamically respond as directed to ad hoc requests and significant plan deviations via a real-time dynamic replanning capability, and easily adapt to technology refreshes. The RSPACE tools will transition to the Air Force and the Navy. ***FY 2018 Plans:*** - Develop a fully integrated software system prototype to demonstrate a distributed concept of operations. - Conduct a series of capability and system-level assessments in conjunction with potential transition partners in preparation for 2019 Air Force experimentation. - Refine models of ISR and counter-ISR capabilities based on Navy guidance following Pacific Fleet (USPACFLT) experiments. - Refine decision aid algorithms and prototype implementations based on Navy guidance following USPACFLT experiments and guidance from Navy transition program of record. - Develop use cases, concepts of operations, and requirements for extension of RSPACE algorithms to the multi-domain (air, space, and cyber) and system of systems command and control problem. - Extend distributed air warfare planning tools to provide land warfighters with targeting, situation awareness, and terrain knowledge. ***FY 2019 Plans:*** - Conduct one or more live-virtual, simulation-based tests in conjunction with a scheduled live Air Force experiment to facilitate transition to the Air Force. - Integrate prototype software with external systems and scale to large, high operational tempo scenarios. - Enhance models and user support interfaces in preparation for transition to operational testing by the Navy. - Commence development of market-based resource prioritization technology. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects the change of emphasis from development and integration to demonstration and experimentation during the final year of the program.			
Title: Systems of Systems-Enhanced Small Units (SESU)	-	6.960	13.124
Description: The System-of-Systems-Enhanced Small Unit (SESU) program will develop and demonstrate adaptive kill-web capabilities based on a system-of-systems architecture that enables a small unit of U.S. forces to prevail against a much larger			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
near-peer adversary force in a contested environment. SESU-developed capabilities will provide the small unit with improved awareness of enemy force composition, disposition, and intent. It will also provide the means to deter escalation of threat, and, if deterrence fails, the ability to destroy enemy combat systems. The goal of the fight will be to push enemy decision makers beyond loss tolerance before they achieve operational objectives. Technologies to accomplish this include command, control, & communications (C3) that operate in a contested environment and interoperate with host-nation forces; distributed sensing, including the ability to leverage indigenous information sources; and hybrid effects that include a mix of kinetic, non-kinetic, and information operations capabilities. A major thrust within the SESU program will be systems architecture and technology to enable manned-unmanned teaming with a focus on C3 and autonomy of the unmanned platforms. SESU technologies will be integrated using system-of-systems principles developed under the System of Systems Integration Technology and Experimentation (SoSITE) program, also budgeted in this Program Element/Project. A Campaign of Learning (CoL) will be conducted in partnership with the Army, and technologies produced by this program will be transitioned to the Services. ***FY 2018 Plans:*** - Begin development of system-of-systems architecture that supports rapid and adaptive kill-web composition. - Begin development of baseline mission scenarios and define SESU components. - Develop architectures for autonomous drones to provide land warfighters with targeting, situation awareness, and terrain knowledge. ***FY 2019 Plans:*** - Demonstrate initial technologies in a simulated environment. - Develop C3 and situation understanding technologies. - Develop plan for live field experimentation. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects a shift in focus from initial development to demonstrations.			
Title: Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS)	-	8.866	17.285
Description: The Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS) program will demonstrate that dynamically composable systems of systems (SoS) provide superior performance and adaptability in the dynamic, uncertain environment posed on U.S. warfighters by urban combat operations. PROTEUS will provide the tools and automation to enable small tactical units to compose force packages optimized to specific urban combat objectives and challenges. These tools will support planning and force composition for all missions relevant to the urban environment: command & control, fires, maneuver, logistics, intelligence, force protection, and medical. PROTEUS will be adaptive to an inherently dynamic and fluid environment that will extend to the social complexity of urban combat as well as kinetic warfighting. Technologies will be integrated using systems of systems principles developed under the System of Systems Integration			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Technology and Experimentation (SoSITE) program, also budgeted in this Program Element/Project. To support concept development, testing, and warfighter interaction, the program will also develop a supporting virtual testbed. Technologies from this program will be transitioned to the Services. ***FY 2018 Plans:*** - Initiate development of a virtual testbed. - Begin development of planning and force composition tools for fires, command and control, and maneuver warfighting functions. - Initiate planning for demonstration of initial capabilities. ***FY 2019 Plans:*** - Develop a multi-resolution scenario within the virtual testbed and compare outcomes against a Marine Corps exercise benchmark. - Define friendly and opposing force systems for kinetic functions. - Demonstrate integration of the virtual testbed and the composition tool using the benchmarked scenario. - Demonstrate adaptive composition capability with Service participants. - Commence development of mathematical tools to define and score the value of materiel in a logistics flow. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects increased effort associated with development and demonstration objectives.			
Title: Retrodirective Arrays for Coherent Transmission (ReACT)	9.615	5.584	-
Description: Worldwide advancements in signal processing and electronics have decreased the effectiveness of single-platform, power-based Electronic Warfare (EW) as a viable technique in the future. The goal of the Retrodirective Arrays for Coherent Transmission (ReACT) program is to develop and demonstrate the capability to combine distributed mobile transmitters to direct high-power spatially resolved radio frequency (RF) beams to a single location. ReACT will achieve this capability by synchronizing multiple distributed transmitters to form a much larger effective array than a single aperture. The key technical challenge is to synchronize distributed and moving transmitters while compensating for platform motion and vibration. The ReACT system will sense the target's emissions and then optimally configure the ReACT transmitters to focus on the area of interest. The ReACT technology is planned to transition to the Air Force and Navy. ***FY 2018 Plans:*** - Continue broadband estimation analysis and algorithm development for accomplishment of program metrics. - Integrate node capabilities, hardware, and externally mounted apertures for a dynamic airborne demonstration on multiple aircraft. - Operate airborne array at suitable test facility with real world scenario/environment.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Finalize transition package for Navy technology demonstration group. - Obtain technical data package, to include Matrix Laboratory (MATLAB) code for other transition paths. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	54.177	67.114	72.402

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
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COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
NET-02: *MARITIME SYSTEMS*	-	135.967	138.112	130.511	-	130.511	126.643	106.465	140.323	147.323	-	-

A. Mission Description and Budget Item Justification

The objective of the Maritime Systems project is to identify, develop, and rapidly mature critical advanced technologies and system concepts for the naval forces role in today's network centric warfare concept. Improvements in communications between and among submarines, surface ships, and naval aircraft have allowed these forces to operate seamlessly with each other and with other service's network centric systems. Naval forces will play an ever-increasing role in network centric warfare because of their forward deployed nature, their unique capability to operate simultaneously in the air, on the sea and under the sea, and their versatile ability to provide both rapid strike and project sustained force. The technologies developed under this project will capitalize on these attributes, improve them, and enable them to operate with other network centric forces.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Cross Domain Maritime Surveillance and Targeting (CDMaST)	16.238	29.869	25.432

Description: The Cross Domain Maritime Surveillance and Targeting (CDMaST) program seeks to identify and implement architectures consisting of novel combinations of manned and unmanned systems to execute long-range kill chains and develop a robust "kill web" against submarines and ships over large contested maritime areas. By exploiting promising new developments in unmanned platforms, seafloor systems, and emerging long-range weapon systems, the program will develop an advanced, integrated undersea and above sea warfighting capability. The Cross Domain Maritime Surveillance and Targeting (CDMaST) program will establish an analytical and experimental environment to explore architecture combinations in terms of operational effectiveness as well as engineering feasibility and robustness. The program will leverage enabling technologies needed for command, control, and communication (C3) between physical domains in order to support the architecture constructs. Through experimentation, the program will not only demonstrate integrated system performance, but also develop new tactics that capitalize on features created by the heterogeneous architecture. The Cross Domain Maritime Surveillance and Targeting (CDMaST) program will invest in technologies that will reduce cost, manage complexity, and improve reliability. Technologies from this program will transition to the Navy.

FY 2018 Plans:
- Continue development of architectures and prepare for experimental operations.
- Finalize experimentation master plan.
- Continue operation and enhancement of the system of systems experimentation environment.
- Initiate spiral experimentation and demonstration of the advanced CDMaST architecture.
- Initiate elemental, engineering and operational tests on selected segments of the CDMaST architecture.
- Conduct Battle Management and Command and Control (BMC2) analysis to evaluate highly resilient kill chains.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop autonomous surface platform architecture for distributed sensing and effects. ***FY 2019 Plans:*** - Integrate system of systems assets and perform operational tests leading to at-sea demonstrations of CDMaST capability to facilitate transition to the Navy. - Continue to refine the CDMaST architecture segments and service layers. - Continue to conduct elemental, engineering, and operational tests on selected segments of the CDMaST architecture. - Complete planning for at sea demonstrations of the CDMaST architecture. - Conduct at-sea demonstrations of the CDMaST architecture. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects reduced testbed development and platform integration efforts.			
Title: Mobile Offboard Command, Control and Attack (MOCCA)	16.799	20.894	18.694
Description: The Mobile Offboard Command, Control and Attack (MOCCA) program seeks to counter the fourth generation submarine signature quieting technology that has significantly degraded passive anti-submarine warfare (ASW) sonar detection range and targeting performance. The MOCCA program will nullify submarine signature reduction trends with active sonar projectors deployed from a mobile unmanned undersea vehicle (UUV) and cooperatively processed with onboard submarine acoustic receive sonar systems. The off-board UUV sonar projector will operate, under positive control, at a significant distance from the cooperative submarine using communication links. The program seeks to achieve breakthrough capability for long-range submarine detection and precision target tracking. The program will develop compact, high output acoustic transducers and novel low probability of intercept/low probability of detection (LPI/LPD) communication signaling. In addition, the MOCCA system will be integrated into submarine onboard sonar and weapons control systems. This program will transition to the Navy. ***FY 2018 Plans:*** - Complete critical technology testing to evaluate at-sea performance of UUV mobile sonar demonstrating source level and beam control, LPI/LPD communications waveforms detectability, range performance and data rate, and sonar processing algorithms. - Complete feasibility and system design trade space studies. - Finalize MOCCA payload UUV packaging and integration studies. - Design, build, and unit test MOCCA sonar and communication payloads and Roll-on/Roll-off processors. - Initiate process for approval of temporary alteration plans for integration of MOCCA sonar and communications Roll-on/Roll-off processors into submarine systems for test and evaluation. - Conduct system utility analysis to identify optimal performance specifications for concept of operations under multiple tactical situations. ***FY 2019 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Perform systems integration of active sonar and communication payload systems aboard test MOCCA UUV platforms. - Perform at-sea functional performance testing of MOCCA active sonar and communications systems. - Conduct integration of MOCCA sonar and communications Roll-on/Roll-off processors on-board a test submarine. - Conduct at-sea MOCCA system demonstration and performance analysis. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects transition from development and demonstrations of competitive system solutions to a single solution integrated into a submarine platform to demonstrate operational performance.			
Title: Positioning System for Deep Ocean Navigation (POSYDON)	24.346	23.718	18.118
Description: The Positioning System for Deep Ocean Navigation (POSYDON) program will provide continuous, Global Positioning System (GPS)-level positioning accuracy to submarines and autonomous undersea vehicles (AUVs) in ocean basins over extended periods of time. Undersea navigation cannot use GPS because the water blocks its signals. At shallower depths, masts can be raised to receive GPS signals, but masts present a detection risk. Typically, the alternative to GPS for undersea navigation has been inertial navigation systems (INS), but INS accuracy can degrade unacceptably over time. The POSYDON program will distribute a small number of acoustic sources, analogous to GPS satellites, around the ocean basin. A submarine or AUV will be equipped with an acoustic receiver and appropriate software in order to obtain, maintain, and re-acquire, if lost, an initial location. By transmitting specific acoustic waveforms and developing accurate acoustic propagation models to predict and interpret the complex arrival structure of the acoustic sources, the submarine or AUV can determine its range from each source and thus trilaterate its position. Technologies developed under this program will transition to the Navy. ***FY 2018 Plans:*** - Complete development of user equipment. - Continue development of the acoustic propagation models and signal waveforms. - Complete development of user equipment ocean models to support real-time ranging. - Demonstrate interference mitigation and anti-spoof capabilities. - Demonstrate real-time undersea positioning with an AUV tracking multiple acoustic sources. ***FY 2019 Plans:*** - Design and test a prototype POSYDON system. - Demonstrate POSYDON system performance and utility for relevant AUV platforms. - Quantify the ability of the POSYDON system to support Navy AUV platform operations. - Document results of at-sea testing for all program phases to support future Navy deep-water development. ***FY 2018 to FY 2019 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
The FY 2019 decrease reflects reduction of at-sea testing.			
Title: Tactical Undersea Network Architecture	20.173	19.973	13.573
Description: Systems fighting as a network are vulnerable to a loss of connectivity in a contested environment. This connectivity is important for synchronizing forces, establishing and maintaining situation awareness, and control of remotely operated vehicles and systems. Additionally, undersea systems are challenged to maintain connectivity and must carry their own energy and operate over their design lifetime with little to no maintenance and repair. These factors inhibit their use in collaborative networks and prevent the full exploitation of the potential of undersea systems. The Tactical Undersea Network Architectures program will overcome these limitations by developing the technologies necessary for autonomous, reliable, and secure undersea data transfers; true plug, play, and operating standards; and rapid, cost effective deployment technologies. The program will develop and demonstrate novel technology options and designs to temporarily restore connectivity for existing tactical data networks in contested environments using small diameter optical fiber and buoy relay nodes. The program will focus on innovative system architecture designs, lightweight optical fiber technologies, and rapidly deployable buoy node designs and component technologies. The Tactical Undersea Network Architectures program will emphasize early risk reduction with future scaled at-sea integrated demonstrations of increasing complexity. Program technologies will transition to the Navy. ***FY 2018 Plans:*** - Test system architecture and information assurance architecture in hardware-in-the-loop simulation. - Complete detailed system design, conduct Critical Design Review, and complete prototype system fabrication. - Complete and publish all environmental compliance documentation. - Complete system integration for and demonstrate at-sea deployment, operation, and connectivity. ***FY 2019 Plans:*** - Complete system integration for and perform at-sea networking demonstration to facilitate transition to the Navy. - Transition interface control and system architecture documentation to Navy. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects the completion of engineering design, build, and unit test efforts.			
Title: Hunter	-	15.250	22.542
Description: The Hunter program seeks to develop novel concepts for Extra Large Unmanned Undersea Vehicles (XLUUVs) to deliver complex payloads. The program will explore efficient encapsulation and buoyancy control concepts to be implemented with advanced fiber handling capabilities for high bandwidth communications in order to create a highly modular and adaptable ocean interface. This interface will give XLUUVs significantly increased payload handling ability and allow them to deliver completely new capabilities previously delivered only by manned platforms. Building upon research conducted under the Cross			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Domain Maritime Surveillance and Targeting (CDMaST) program budgeted in this PE/Project, the Hunter program will establish a new capability for integration into maritime system of systems warfare architectures. Technologies developed under the Hunter program will transition to the Navy. ***FY 2018 Plans:*** - Develop preliminary advanced payload controller interface. - Develop system requirements for the Hunter payload delivery carriage and host vehicle integration. - Complete preliminary system design of the Hunter payload delivery carriage. - Initiate information assurance analysis of payload delivery carriage. ***FY 2019 Plans:*** - Complete design of Hunter payload delivery carriage. - Fabricate Hunter payload delivery carriage. - Perform stand-alone in-water test of Hunter payload delivery carriage. - Apply information assurance measures to Hunter payload delivery carriage. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects the initiation of fabrication and testing of the system and initial integration with the XLUUV vehicle.			
Title: Tactical Exploitation of the Acoustic Channel (TEAC)	-	13.350	23.152
Description: The Tactical Exploitation of the Acoustic Channel (TEAC) program will provide the capability to coherently combine acoustic energy from a distributed network of underwater acoustic sources to improve signal transmission in an undersea environment. The ability to cohere multiple underwater sensors will have a transformative impact on a number of compelling applications including surveillance, communications, and vehicle positioning. For all of these applications, coherent sensor gain is currently achieved by deploying large, costly, and cumbersome cabled arrays. Based on technologies explored in the Mobile Offboard C2 and Attack (MOCCA) program, budgeted in this PE/Project, the TEAC program will create the opportunity to deploy groups of low unit-cost sources that work cooperatively and semi-autonomously to focus energy undersea. This concept would provide an extensible, affordable, and flexible method to harness the rapid development of undersea vehicles, ocean energy sources, and new acoustic source technologies. Technologies developed under this program are intended to transition to the Navy. ***FY 2018 Plans:*** - Develop underwater source positioning requirements and identify alignment strategies. - Begin system architecture design and acoustic propagation modeling. - Develop the fixed source network, algorithms, and signal waveforms for at-sea demonstration.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Develop a model for multi-vehicle representation, which will serve as a baseline for the maritime collaborative networks. ***FY 2019 Plans:*** - Demonstrate and test at-sea cohering of acoustic sources. - Analyze sea-test data to identify system performance robustness. - Begin development of motion mitigation algorithms. - Begin development of command and control for a semi-autonomous distributed system. - Develop concept of operations for TEAC system deployment. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects large-scale testing.			
Title: Ocean of Things ***Description:*** The goal of the Ocean of Things program is to advance maritime sensing and battlespace awareness and provide non-lethal maritime effects using low-power microelectronics and advanced data analytics. Ocean of Things builds upon advances made in the Cross Domain Maritime Surveillance and Targeting (CDMaST) program, which is also in this Program Element. Ocean of Things will develop large numbers of heterogeneous sensing and effects platforms to cover large ocean areas. These platforms will leverage satellite communications to populate a large data repository with sensor outputs for shared processing. Ocean of Things will apply advanced analysis techniques to the stored data to synthesize and discover new signals and behaviors in the ocean environment. The program will research the spatio-temporal composability of sensors and develop applications for distributed platform behavior using an internet of things architecture deployed across the world's oceans. Further research will examine additional platform capabilities and system impacts of various communication rates and platform behaviors. The Ocean of Things program will improve ocean awareness and provide access to areas not covered by existing platforms. Technologies developed in Ocean of Things will transition to the Navy. ***FY 2019 Plans:*** - Conduct initial sensor and payload studies to examine optimal sensor and payload types for platform configurations. - Develop initial hardware design and sensor configurations for test platform delivery. - Prepare data platform, model ocean inputs and design initial machine learning applications. - Develop advanced platform design. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.	-	-	9.000
Title: Hydra	32.682	7.558	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Hydra program will develop and demonstrate advanced capabilities for the undersea deployment and employment of unique payloads. Hydra integrates existing and emerging technologies and the ability to be positioned in the littoral undersea battlespace to create a disruptive capability. The system consists of a modular enclosure with communications, command and control, energy storage, and standard interfaces for payload systems. The modular enclosures are deployed by various means, depending on the need for speed and stealth, and remain deployed until awakened for employment. Hydra will develop critical enabling technologies for energy storage and recharging, communications, command and control, deployment, and autonomous operations. Technology developed under this program is transitioning to the Navy. ***FY 2018 Plans:*** - Complete modular enclosure demonstration. - Launch air vehicle from undersea. - Continue testing of alternative payload deployment methods, and conduct at-sea demonstration. - Complete testing of undersea-launched air vehicle. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion and transition of technologies from this program to the Navy.			
Title: Hybrid Multi Material Rotor Full Scale Demonstration (HyDem)	7.500	3.000	-
Description: The goal of the Hybrid Multi Material Rotor Full Scale Demonstration (HyDem) program is to dramatically improve U.S. Navy submarine superiority. HyDem will apply breakthroughs in materials and material system technologies, and multi-disciplinary design methods to a Virginia Class submarine propulsor, a critical component in submarine performance. The U.S. Navy's ability to operate their submarine fleet with improved capability allows for the creation of strategic surprise. Submarines could exploit expanded areas that were previously unattainable for the purpose of submarine warfare, including antisubmarine warfare (ASW), antisurface warfare (ASuW), intelligence, surveillance and reconnaissance (ISR) gathering, strike, Special Forces operations, and strategic deterrence missions. The HyDem program will design, manufacture, and supply the Navy with a novel component for integration into a new construction Virginia Class submarine. The Navy will evaluate this component in sea trials. It is envisioned that the Navy will integrate this design change into the future development of the Virginia Class and Ohio Replacement submarines, and back-fit previously constructed Virginia Class submarines. Technology developed under this program is transitioning to the Navy. ***FY 2018 Plans:*** - Complete sea trials of the propulsor on a Virginia Class submarine. - Complete naval shafting applications study.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Deliver a scaled shafting component. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion and transition to the Navy.			
Title: Blue Wolf ***Description:*** Undersea platforms have inherent operational and tactical advantages such as stealth and surprise. Platform drag due to fluid viscosity and platform powering requirements varies with the speed through the water. Platform energy and power density limitations create two distinct operational usage profiles: one for unmanned undersea vehicles (low speed, long endurance) and another for undersea weapons (high speed, short endurance). Designers have historically solved this with hybrid systems such as the Navy's Vertical Launch Anti-Submarine Rocket, or by increasing the size of undersea systems. However, hybrid systems can be vulnerable to air and undersea defensive systems and larger undersea systems can result in significant launch platform modifications. The Blue Wolf program seeks to provide a radically different solution to develop and demonstrate an undersea demonstrator vehicle with endurance and speed capabilities beyond conventional undersea systems within the weight and volume envelopes of current Navy undersea systems. Significant technical challenges to be addressed include: dynamic lift and drag reduction, hybrid energy system development compatible with existing manned platform safety requirements and certification, and system integration and demonstration in at-sea environment. The program will leverage Navy connectivity, autonomy, guidance, navigation, and obstacle avoidance technologies. Under an existing Memorandum of Agreement, following vehicle integration and initial testing, the program will transition to the Navy. ***FY 2018 Plans:*** - Complete battery module and system safety testing and analysis. - Complete test vehicle system integration and checkouts. - Complete demonstration vehicle system integration. - Conduct demonstration vehicle testing from barge in controlled area. - Complete system safety approval for at sea testing. - Transition to the Navy. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.	15.140	4.500	-
Title: Virtual Acoustic Microphone System (VAMS) ***Description:*** The Virtual Acoustic Microphone System (VAMS) program developed additional acoustic sensor capabilities for underwater platforms. The VAMS program sought to develop and demonstrate technologies that enable projection of underwater acoustic sensor arrays with performance comparable to existing arrays. The VAMS approach combined novel transmitters with	3.089	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
novel signal extraction methods and exploit new and emerging high-speed sensor and processor capabilities which are not currently possible with existing technology. The acoustic sensor technology developed under the VAMS program transitioned to the Navy.			
Accomplishments/Planned Programs Subtotals	135.967	138.112	130.511

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	Project (Number/Name) NET-06 / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	227.682	234.160	235.656	-	235.656	204.050	149.500	83.200	30.000	-	-

A. Mission Description and Budget Item Justification

This project funds classified DARPA programs that are reported in accordance with Title 10, United States Code, Section 119(a)(1) in the Special Access Program Annual Report to Congress.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Classified DARPA Program	227.682	234.160	235.656
Description: This project funds Classified DARPA Programs. Details of this submission are classified.			
FY 2018 Plans: Details will be provided under separate cover.			
FY 2019 Plans: Details will be provided under separate cover.			
FY 2018 to FY 2019 Increase/Decrease Statement: Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	227.682	234.160	235.656

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Details will be provided under separate cover.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	239.391	210.123	190.128	-	190.128	272.997	303.098	277.758	276.964	-	-
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	26.966	37.843	34.644	-	34.644	28.901	20.401	13.401	8.401	-	-
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	134.174	107.813	86.610	-	86.610	212.796	276.697	264.357	268.563	-	-
SEN-06: *SENSOR TECHNOLOGY*	-	78.251	64.467	68.874	-	68.874	31.300	6.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Sensor Technology program element is budgeted in the Advanced Technology Development Budget Activity because it funds sensor efforts that will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability and battle damage assessment.

The Surveillance and Countermeasures Technology project will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability, and battle damage assessment. Timely surveillance of enemy territory under all weather conditions is critical to providing our forces with the tactical information needed to succeed in future wars. This operational surveillance capability must continue to perform during enemy efforts to deny and deceive the sensor systems, and operate, at times, in a clandestine manner. This project will exploit recent advances in multispectral target phenomenology, signal processing, low-power high-performance computing, and low-cost microelectronics to develop advanced surveillance and targeting systems. In addition, this project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats.

The Sensors and Processing Systems project develops and demonstrates the advanced sensor and processing technologies and systems necessary for Intelligence, Surveillance, and Reconnaissance (ISR) missions. Future battlefields will continue to be populated with targets that use mobility and concealment as key survival tactics, and high-value targets will range from specific individual insurgents and vehicles to groups of individuals and large platforms such as mobile missile launchers and artillery. The Sensors and Processing Systems Project is primarily driven by four needs: (a) providing day-night ISR capabilities against the entire range of potential targets; (b) countering camouflage, concealment, and deception of mobile ground targets; (c) detecting and identifying objects of interest/targets across wide geographic areas in near-real-time; and (d) enabling reliable identification, precision fire control tracking, timely engagement, and accurate battle damage assessment of ground targets.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	241.288	210.123	177.278	-	177.278
Current President's Budget	239.391	210.123	190.128	-	190.128
Total Adjustments	-1.897	0.000	12.850	-	12.850
• 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	2.103	0.000			
• SBIR/STTR Transfer	-4.000	0.000			
• TotalOtherAdjustments	-	-	12.850	-	12.850

Change Summary Explanation

FY 2017: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.

FY 2018: N/A

FY 2019: Increase reflects initiation of several programs in the Sensors and Processing Systems project.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603767E / *SENSOR TECHNOLOGY*	Project (Number/Name) SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	26.966	37.843	34.644	-	34.644	28.901	20.401	13.401	8.401	-	-

A. Mission Description and Budget Item Justification

The Surveillance and Countermeasures Technology project funds sensor efforts that will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability, and battle damage assessment. Timely surveillance of enemy territory under all weather conditions is critical to providing our forces with the tactical information needed to succeed in future wars. This operational surveillance capability must continue to perform during enemy efforts to deny and deceive the sensor systems, and operate, at times, in a clandestine manner. This project will exploit recent advances in multispectral target phenomenology, signal processing, low-power high-performance computing, and low-cost microelectronics to develop advanced surveillance and targeting systems. In addition, this project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Aerial Dragnet	9.984	14.090	18.230

Description: Aerial Dragnet seeks to detect multiple small Unmanned Aerial Systems (UAS) in complex and/or urban terrain before they are within Line-Of-Sight (LOS) of friendly assets. Unlike traditional air targets, small UASs pose a special threat in urban terrain for several reasons: they can fly at low altitudes between buildings, they are small making them difficult to sense, and they move at slow speeds making them difficult to differentiate from other movers. Moreover, the development of small UASs is driven by commercial technologies, which make them rapidly adaptable and very easy to use. Building upon research conducted in the System of Systems Integration Technology and Experimentation (SoSITE) program (budgeted in PE 0603766E, Project NET-01), Aerial Dragnet will perform surveillance using an architecture consisting of networked sensors mounted on distributed aerial platforms. The ability to see over and into urban terrain allows an Aerial Dragnet to rapidly detect, track, and classify UAS incursions, thus enabling multiple defeat options. This program focuses on the development of payloads, to be hosted on unmanned aerial platforms, comprising of signal processing software, sensor hardware, and networking for distributed, autonomous operation. The system will be scalable to provide cost-effective surveillance coverage from neighborhood to city-sized areas. Aerial Dragnet technologies are expected to transition to the Army and Marines with particular relevance to missions in the EUCOM and CENTCOM Area of Responsibilities (AORs).

FY 2018 Plans:

- Conduct engineering subsystem tests to assess small UAS detection performance in an instrumented urban test area.
- Complete development of initial hardware sensor payloads.
- Evaluate software for non-line-of-sight UAS tracking and classification.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Demonstrate and test system performance over a neighborhood-sized urban area. ***FY 2019 Plans:*** - Update hardware sensor payloads to reduce size, weight, power, and cost. - Network multiple aerial surveillance platforms to increase coverage. - Develop autonomy algorithms to allow surveillance platforms to adapt to urban terrain. - Demonstrate and test the performance of the system in a multi-neighborhood-sized urban area. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects the expanded integration and testing of the system.			
Title: Blue Note ***Description:*** Blue Note seeks to perform Terrain Scattered Jamming (TSJ) against surveillance radars, where radar signals are scattered off the ground into the threat radar receive beam. Blue Note, expanding on methods developed under the Retrodirective Arrays for Coherent Transmission (ReACT) program (budgeted in PE 0603766E, Project NET-01), will develop new ways of acquiring the threat radar's waveform, which is required to execute TSJ. Blue Note will also design new terrain scattered jamming waveforms to make it more difficult to mitigate and more effective at longer ranges from the threat radar. Technologies developed under the Blue Note program will transition to the Services. ***FY 2018 Plans:*** - Commence development of new methods for acquiring threat radar waveforms. - Commence design and analysis of new jamming waveforms. - Conduct initial data collection using existing U.S. radars. ***FY 2019 Plans:*** - Develop hardware to reduce system latency. - Refine jamming waveforms to manage more advanced threats. - Develop performance assessment tools. - Demonstrate real-time operation of an integrated system. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The increase in FY 2019 reflects more complex testing of the integrated system.	-	9.785	16.414
Title: Multi-Optical Sensing (MOS) ***Description:*** The proliferation of Radio Frequency (RF)-based countermeasures, such as Digital Radio Frequency Memory (DRFM), has presented challenges to the effectiveness of data sensors. The Multi-Optical Sensing (MOS) program will enable an alternative approach to detecting, tracking, and performing non-cooperative target identification, as well as providing fire	16.982	13.968	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
control for fighter class and long-range strike aircraft. This program leverages emerging high-sensitivity Focal Plane Array (FPA) and compact, multi-band laser systems technology in the near/mid/long-wave infrared bands to enable the development of a multi-optical sensing system. Technical challenges include the demonstration of inexpensive, multi-band, large-format, photon-counting, high-bandwidth receivers and their integration into a multi-optical sensor suite compatible with airborne assets. The MOS program seeks to advance the state of the art of components and technology to support an all-optical airborne system that can detect, geolocate, and identify targets at standoff ranges. Technologies from this program will transition to the Air Force. ***FY 2018 Plans:*** - Perform analysis of flight data to demonstrate the impact of a multi-mode airborne laser radar system. - Complete development of high-power laser system. - Transfer technology and hardware to Air Force. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	26.966	37.843	34.644

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603767E / *SENSOR TECHNOLOGY*	Project (Number/Name) SEN-02 / *SENSORS AND PROCESSING SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	134.174	107.813	86.610	-	86.610	212.796	276.697	264.357	268.563	-	-

A. Mission Description and Budget Item Justification

The Sensors and Processing Systems project develops and demonstrates the advanced sensor and processing technologies and systems necessary for Intelligence, Surveillance, and Reconnaissance (ISR) missions. Future battlefields will continue to be populated with targets that use mobility and concealment as key survival tactics, and high-value targets will range from specific individual insurgents and vehicles to groups of individuals and large platforms such as mobile missile launchers and artillery. The Sensors and Processing Systems Project is primarily driven by four needs: (a) providing day-night ISR capabilities against the entire range of potential targets; (b) countering camouflage, concealment, and deception of mobile ground targets; (c) detecting and identifying objects of interest/targets across wide geographic areas in near-real-time; and (d) enabling reliable identification, precision fire control tracking, timely engagement, and accurate battle damage assessment of ground targets. The Sensors and Processing Systems Project develops and demonstrates technologies and system concepts that combine novel approaches to sensing with emerging sensor technologies and advanced sensor and image processing algorithms, software, and hardware to enable comprehensive knowledge of the battlespace and detection, identification, tracking, engagement, and battle damage assessment for high-value targets in all weather conditions and combat environments.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Spatial, Temporal and Orientation Information for Contested Environments (STOIC)	20.365	15.632	7.103
Description: The Spatial, Temporal and Orientation Information for Contested Environments (STOIC) program will enable precision cooperative effects by developing global time transfer and synchronization systems independent of GPS. As a corollary to time synchronization, this program will also enable GPS-independent positioning to maintain precise time synchronization between collaborating mobile users. Key attributes of this program are global availability, minimal and low cost infrastructure, anti-jamming capability, and performance equal to or better than GPS through recent advances in optical clocks and time transfer. Demonstrations on relevant platforms in relevant environments will be used to validate the technology. This program will transition to the Services, emphasizing platforms that operate in GPS-denied environments.			
FY 2018 Plans: - Conduct real-time demonstrations of jam-proof very low frequency (VLF) based positioning system. - Complete validation of optical clock components for long-term performance. - Conduct real-time demonstration of precision time transfer using tactical data link signals.			
FY 2019 Plans: - Conduct field demonstrations of VLF-based positioning system with ionospheric modeling correction to validate performance in a relevant environment.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Initiate transition of VLF-based positioning system to Army and Navy acquisition programs. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects completion of major testing and demonstration efforts in FY 2018.			
Title: Automatic Target Recognition (ATR) Technology ***Description:*** Automatic Target Recognition (ATR) systems provide the capability to detect, identify, and track high value targets from collected sensor data. Current ATRs are typically designed for specific sensors and static due to pre-programmed target lists and operating mode, limiting mission execution capabilities. Extending ATR Technology to accommodate sensor upgrades or include new emerging targets can be costly and time consuming. The objective of the ATR Technology program is to develop technologies that reduce operation limitations while also providing significant performance improvements, dramatically reduced development times, and reduced life cycle maintenance costs. Recent breakthroughs in deep learning, sparse representations, manifold learning, and embedded systems offer promise for dramatic improvements in ATR Technology. The program will focus on three core areas: (1) development of on-line adaptive algorithms that enable performance-driven sensing and ATR technology; (2) recognition technology that enables rapid incorporation of new targets; and (3) technologies that dramatically reduce required data rates, processing times, and the overall hardware and software footprint of ATR systems. ATR technology developed under the program is planned for transition to the Services. ***FY 2018 Plans:*** - Continue to improve ATR algorithm performance, focusing on reducing processing times and system size and power requirements. - Develop flightworthy prototype, low-power ATR processing hardware that executes the ATR algorithm in real-time. - Demonstrate Open Mission System (OMS) enabled ATR operation in tactical radar System Integration Laboratory (SIL). - Prepare for a flight demonstration of ATR algorithms running on an airborne platform. - Conduct flight verification of ATR hardware and software and perform flight demonstration of ATR algorithms operating on an airborne platform. ***FY 2019 Plans:*** - Conduct additional flight demonstrations of ATR algorithms operating on an airborne platform to facilitate transition to the Services. - Expand ATR application to new radar sensor mode and demonstrate in laboratory environment. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects fewer testing and data collection requirements.	23.759	15.352	8.369
Title: Seeker Cost Transformation (SECTR)	19.002	15.989	5.350

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The Seeker Cost Transformation (SECTR) program will develop novel weapon terminal sensing and guidance technologies and systems, for air-launched and air-delivered weapons, that can: (1) find and acquire fixed and moving targets with only minimal external support; (2) achieve high navigation accuracy in a GPS-denied environment; and (3) have very small size and weight, and potentially low cost. The development objectives are technologies and systems with small Size, Weight and Power (SWaP), low recurring cost, applicability to a wide range of weapons and missions such as small unit operations, suppression of enemy air defenses, precision strike, and time-sensitive targets. The technical approach for the sensing/ processing hardware is to use both passive electro-optical infrared (EO/IR) sensors, which have evolved into very small and inexpensive devices in the commercial market, and a reconfigurable processing architecture, such as the architecture developed in DARPA's Adaptable, Low Cost Sensors (ADAPT) program. The program will also develop a Government-owned open architecture for the seeker with standardized interfaces between components (both hardware and software). The technical approach to target recognition will start from "deep learning" and 2D/3D machine vision algorithms pioneered for facial recognition and the identification of critical image features. Technologies developed under this program will transition to the Services. ***FY 2018 Plans:*** - Integrate prototype SECTR seeker including all GPS-free navigation and novel target recognition subsystems into the seeker system. - Conduct prototype SECTR seeker performance laboratory tests. - Perform integration of prototype SECTR seeker with one or more Precision Guided Munition (PGM) platforms. - Demonstrate prototype SECTR seeker performance in hardware-in-the-loop (HWIL) tests simulating flight with integrated PGM platforms. ***FY 2019 Plans:*** - Conduct prototype SECTR seeker and PGM captive-carry flight tests and HWIL tests. - Conduct free-flight test of integrated prototype SECTR seeker-guided PGM. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects shifting from prototype development to prototype SECTR seeker captive-carry flight tests and free-flight tests.			
Title: Small Satellite Sensors	23.478	27.651	20.970
Description: The Small Satellite Sensors program will develop and space-qualify electro-optical and infrared (EO/IR) sensor and inter-satellite communications technologies, and establish feasibility that new DoD tactical capabilities can be implemented on small (< 100 kg) satellites. Experimental payloads will be flown on small satellites, and data will be collected to validate new operational concepts. Small satellites provide a low-cost and quick-turnaround capability for testing new technologies and experimental payloads. Operationally, small and low-cost satellites enable the deployment of larger constellations which can			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
provide greater coverage, persistence, and survivability compared to a small number of more expensive satellites, as well as the possibility for launch-on-demand. This program seeks to leverage rapid progress being made by the commercial sector on small satellite bus technology, as well as investments being made by DoD and industry on low-cost launch and launch-on-demand capabilities for small satellites. The program will focus on developing, demonstrating, and validating key payload technologies needed by DoD that are not currently being developed for commercial space applications. Technologies developed under this program will transition to the Air Force. ***FY 2018 Plans:*** - Complete construction, integration, and ground testing of all experimental satellites. - Implement direct-to-user data link hardware and software on at least one satellite. - Demonstrate on-board image processing. - Develop ground-segment receivers and experimentation plan for real-time demonstrations. - Deliver first EO/IR satellite for launch into low earth orbit. ***FY 2019 Plans:*** - Launch satellites and conduct on-orbit operations including mission planning, payload testing, and image collection. - Downlink raw imagery for ground processing and pre-processed imagery for comparative analysis. - Perform data collection campaigns and analyze experimental data from satellites. - Perform inter-satellite communications link tests and coordinated multi-satellite operations. - Demonstrate feasibility of novel real-time tactical operational concepts. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects the completion of all satellite design and fabrication efforts, with program focus shifting to final launches and the on-orbit experimental operations and data analysis.			
Title: Dynamically Composed RF Systems ***Description:*** Dominance of the Radio Frequency (RF) spectrum is critical to successful U.S. military operations. Radar systems, Electronic Warfare (EW) systems, and communication systems require custom software and hardware that is costly and time consuming to build and integrate onto platforms. The Dynamically Composed RF Systems program addresses these challenges by developing adaptive, converged RF array systems. This enables enhanced operational capability by dynamically adapting the system for tasks to support radar, communications, and EW in a converged manner. This program will design and develop: (1) a modular architecture for collaborative, agile RF systems; (2) advanced techniques for RF apertures and airframe integration and the associated wide-band agile electronics to support converged missions over those apertures; (3) a heterogeneous signal processing complex implementing hardware-agnostic RF operating modes (the RF Virtual Machine); (4) software tools for the control, coordination, and scheduling of RF functions and payloads at the element level to maximize overall task performance	14.450	20.689	12.080

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
(a system and sensor resource manager (SSRM)). This capability can be adapted to address diverse missions. Technology developed under this program will transition to the Services. ***FY 2018 Plans:*** - Demonstrate SSRM algorithms and software approach for controlling and scheduling RF hardware to execute converged RF functions. - Select prototype system architecture and begin detailed design of converged RF payload. - Design RF Virtual Machine performing RF processing on heterogeneous processing complexes. - Conduct laboratory testing on RF Virtual Machine to confirm validity of design approach. - Design converged RF front end and apertures to address bandwidth, field of view, and sensitivity goals commensurate with the prototype system architecture and the limitations of compact platforms / unmanned aerial vehicles (UAV). - Design and begin implementation of SSRM software to control and schedule the RF hardware to execute converged RF missions with functional and spectral flexibility. ***FY 2019 Plans:*** - Conduct laboratory testing on prototype converged RF front end and apertures to demonstrate that hardware will meet goals for bandwidth, field of view, and sensitivity. - Complete system design and validate that the system will meet the program goals. - Develop integration plan describing how the converged RF payload will be installed into the target platform. - Complete system interface control documents defining interfaces between the system, the payload, and off-board controllers. - Complete initial version of the SSRM software. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program evolution from technology maturation to specific integrated system design.			
Title: Video-rate Synthetic Aperture Radar (ViSAR) ***Description:*** Recent conflicts have demonstrated the need for close air support by precision attack platforms such as the AC-130J aircraft in support of ground forces. Under clear conditions, targets are easily identified and engaged quite effectively, but in degraded environments, the atmosphere can inhibit traditional optical sensors. The AC-130J must fly above cloud decks in order to avoid anti-aircraft fire, negating optical targeting sensors. Similarly, rotary/wing blades in urban operations generate copious amounts of dust that prevent circling assets from supplying cover fire for ground forces. The Video-rate Synthetic Aperture Radar (ViSAR) program will develop a real-time spotlight Synthetic Aperture Radar (SAR) imaging sensor that provides imagery of a region to allow high-resolution fire direction in conditions where optical sensors do not function. Technology from this program is anticipated to transition to the Special Operations Command (SOCOM).	4.500	3.300	3.150

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
FY 2018 Plans: - Commence development of video SAR image processing technology. ***FY 2019 Plans:*** - Continue development of video SAR image processing technology. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects minor program repricing.			
Title: All-Signal Tactical Real-Time Analyzer (ASTRAL)	-	5.000	12.769
Description: The All-Signal Tactical Real-time Analyzer (ASTRAL) program will develop and demonstrate a system for radio frequency and optical Electromagnetic (EM) signal surveillance and environment understanding. Building on technologies explored under the Dynamically Composed RF Systems program, also in this Program Element/Project, the objective of ASTRAL is to provide a factor of at least 1000 times improvement over current signal awareness processing speed over broad spectral coverage. The program will use technology that supports a development path leading to a mobile, tactical capability. The development objectives of the ASTRAL program are to (1) develop a hybrid processor that provides real-time processing of the most challenging Low-Probability-of-Intercept (LPI) threat signals across a wide bandwidth, and (2) identify exploitation algorithms for military applications that are well-suited to this type of hybrid processor. Several strategic and tactical spectrum awareness applications addressed include (a) real-time exploitation of optical communications, (b) city-wide wireless device geo-location, (c) broadband LPI radar warning, and (d) theater-wide spread-spectrum LPI radio geo-location. ASTRAL will transition to the Services and Intelligence Community. ***FY 2018 Plans:*** - Explore development of ultra-wide-band and high-speed signal processing. - Design a brassboard hybrid signal processor capable of discovering LPI signals. ***FY 2019 Plans:*** - Identify hybrid processor architectures suited for a wide range of tactical military signal awareness applications. - Integrate the brassboard hybrid signal processor system. - Demonstrate LPI signal processing at broad bandwidth in a laboratory environment with simulated and real signal inputs. - Select hybrid processor architectures for specific tactical military application development. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects increased signal process integration and demonstrations.			
Title: 3DNow	-	-	5.783

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Description: The 3DNow program aims to develop technologies that let warfighters rapidly access tactical 3D situational awareness data within a secure government owned framework built on a commercial technology base. Building on ideas explored in the System of Systems Enhanced Small Units (SESU) program (budgeted in PE 0603766E, Project NET-01), 3DNow will leverage the latest trends in image processing algorithms, embedded systems, portable devices, and assured separation kernel software to build an interface layer that securely connects the latest commercial hardware to the rest of the military infrastructure. In order to mature and demonstrate the concept, 3DNow will conduct several development cycles focused on supporting tactical level urban warfare. New technologies to be developed include mapping algorithms, image processing algorithms, and interoperability software and hardware. This new technology will interface with commercial drones, Software Defined Radios (SDR), advanced sensors such as those found in self-driven cars (miniature radars and lidars), high-resolution imagers, and Internet of Things (IoT) devices. 3DNow will transition the framework and sample systems to the Services. ***FY 2019 Plans:*** - Develop program plan and work with Service partners to define capabilities. - Define focus of development cycles. - Commence development of first generation interface layer. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.			
Title: Cognitive Maneuver	-	-	11.036
Description: The Cognitive Maneuver program will build decision aids for gray zone scenarios, where adversaries attempt to manipulate a U.S.-allied nation through the use of both kinetic and non-kinetic means. Based on research performed under the Resilient Synchronized Planning & Assessment Contested Environment (RSPACE) program (budgeted in PE 0603766E, Project NET-01), the purpose of the Cognitive Maneuver program is to reduce ambiguity and reveal intent of gray zone actors who use techniques such as misinformation and intimidation to destabilize host nations and possibly produce advantageous conditions for military engagements. The tools produced by Cognitive Maneuver will automate gray zone information operations, and help U.S. Forces adapt to changing conditions and adversary responses. Instead of relying on passive collection of sensory data, Cognitive Maneuver will employ active sensing, and recommend actions U.S. forces and allied partners can take to stimulate the environment and reveal any hostile strategies. To achieve this goal, Cognitive Maneuver will build and demonstrate tools to 1) develop a dynamic model of hostile activities in a gray zone environment, 2) assess the decision space to recommend which actions may provide the highest value information, and 3) monitor execution of these actions to assess incremental progress toward reducing the ambiguity of the operating environment and suggest adjustments. Cognitive Maneuver will transition to the Services.			

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
FY 2019 Plans: - Develop a taxonomy for cognitive maneuver. - Design gray zone modeling, initial algorithms for action generation, and initial development of monitor and assessment tools. - Build a library of real and synthetic data and a laboratory simulation test environment. - Commence development of technology to networked urban sensors to create a situation awareness picture. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects program initiation.			
Title: Adaptive Radar Countermeasures (ARC) ***Description:*** The Adaptive Radar Countermeasures (ARC) program will pursue new algorithms for rapidly protecting DoD systems against new or unknown radar-based threats. Protecting these systems currently relies on uniquely identifying an enemy radar and applying an appropriate, pre-programmed Electronic Countermeasure (ECM), which can take years to develop. The emergence of digitally-programmed radars that exhibit novel behaviors and agile waveform characteristics, however, has made this approach to countering radar-based threats increasingly challenging. Developing new ECM over several years is no longer sufficient. ARC will therefore pursue new processing techniques and algorithms that adapt in real-time to generate suitable countermeasures. Using techniques such as machine learning and artificial intelligence, ARC will learn the behavior of the threat system and then choose and implement an appropriate countermeasure strategy. The program is planned for transition to Air Force, Navy, and Marine Corps airborne electronic warfare systems. ***FY 2018 Plans:*** - Conduct testing of ARC against advanced, complex radar signals in static and open-air testing environments. - Deliver ARC technology to Service transition partners for inclusion into identified airborne platforms. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects program completion and transition to Air Force, Marine Corps, and Navy.	19.487	4.200	-
Title: Advanced Scanning Technology for Imaging Radars (ASTIR) ***Description:*** The Advanced Scanning Technology for Imaging Radars (ASTIR) program provided immediate benefit to applications that are constrained by power, weight, and the complexity limits of production. The goal of this program was to demonstrate a new imaging radar architecture using an electronically scanned sub-reflector to produce a more readily available, cost-effective sensor solution that does not require platform or target motion. Key system attributes included: (1) high-resolution 3D imaging for enhanced identification and targeting, independent of platform or target motion; (2) video frame rates to provide well-focused images even when there is platform or target motion; (3) beam steer with a single transmit/receive chain to reduce system complexity resulting in lower cost, power, and weight; and (4) millimeter-wave (mmW)/terahertz (THz) electronic	5.593	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency		Date: February 2018
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
component advancements from other DARPA programs for transmit and receive functions. This program resulted in a more readily available, cost-effective imaging radar technology that works in concert with a wide area surveillance system to provide target identification at video frame rates in all conditions where existing sensors do not work. Candidate military applications include efficient terminal seekers, imaging systems for defense of shipping in ports and littoral environments, base perimeter monitoring, and screening of personnel passing through access control points. Technology developed under this program transitioned to the Air Force.			
Title: Multifunction RF (MFRF) ***Description:*** The Multifunction RF (MFRF) program enabled U.S. rotary wing aircraft forces to fight effectively in all forms of severely Degraded Visual Environments (DVE) when our adversaries cannot. The program went beyond landing aids in DVE to address all elements of combat to include landing, takeoff, hover/taxi, in route navigation, lethality, and survivability. Building on previous RF sensors advancements, the program sought to eliminate many redundant RF elements of current independently developed situational and combat support systems to provide multifunction capability with flexibility of adding new mission functions. This reduced the overall Size, Weight, Power, and Cost (SWaP-C) of subsystems and protrusive exterior antennas on military aircraft, enabling greater mission capability with reduced vehicle system integration burden. The program approach included: (1) development of synthetic vision for pilots that fuses sensor data with high-resolution terrain databases; (2) development of Advanced Rotary Multifunction Sensor (ARMS), utilizing silicon-based tile arrays, for agile electronically scanning technology at low SWaP-C; and (3) implementation of software development kit to re-define modes as required by mission or platform needs, and ease of adding new modes via software without hardware modifications. Technology developed under this program transitioned to the Army.	3.540	-	-
Accomplishments/Planned Programs Subtotals	134.174	107.813	86.610

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2A, RDT&E Project Justification: PB 2019 Defense Advanced Research Projects Agency			Date: February 2018
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603767E / *SENSOR TECHNOLOGY*	Project (Number/Name) SEN-06 / *SENSOR TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
SEN-06: *SENSOR TECHNOLOGY*	-	78.251	64.467	68.874	-	68.874	31.300	6.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

This project funds classified DARPA programs that are reported in accordance with Title 10, United States Code, Section 119(a)(1) in the Special Access Program Annual Report to Congress.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Classified DARPA Program	78.251	64.467	68.874
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2018 Plans:*** Details will be provided under separate cover. ***FY 2019 Plans:*** Details will be provided under separate cover. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	78.251	64.467	68.874

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Details will be provided under separate cover.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605001E / *MISSION SUPPORT*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	69.244	63.769	65.646	-	65.646	66.152	66.901	67.667	68.450	-	-
MST-01: *MISSION SUPPORT*	-	69.244	63.769	65.646	-	65.646	66.152	66.901	67.667	68.450	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Mission Support Program Element provides funding for the costs of mission support activities for the Defense Advanced Research Projects Agency. The funds provide personnel compensation for mission support civilians as well as costs for building rent, physical security, travel, supplies and equipment, communications, printing and reproduction.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	69.244	63.769	66.051	-	66.051
Current President's Budget	69.244	63.769	65.646	-	65.646
Total Adjustments	0.000	0.000	-0.405	-	-0.405
• 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			
• TotalOtherAdjustments	-	-	-0.405	-	-0.405

Change Summary Explanation

FY 2017: N/A

FY 2018: N/A

FY 2019: Decrease reflects minor repricing.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Mission Support	69.244	63.769	65.646
Description: Mission Support			
FY 2018 Plans:			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605001E / *MISSION SUPPORT*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
- Fund mission support civilian salaries and benefits, and administrative support costs. - Fund travel, rent and other infrastructure support costs. - Fund security costs to continue access controls, uniformed guards, and building security requirements. ***FY 2019 Plans:*** - Fund mission support civilian salaries and benefits, and administrative support costs. - Fund travel, rent and other infrastructure support costs. - Fund security costs to continue access controls, uniformed guards, and building security requirements. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 increase reflects increased costs associated with rent, security, and infrastructure support costs.			
Accomplishments/Planned Programs Subtotals	69.244	63.769	65.646

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605502E / *SMALL BUSINESS INNOVATION RESEARCH*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	94.860	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
SB-01: *SMALL BUSINESS INNOVATION RESEARCH*	-	94.860	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

In accordance with Public Law No: 115-91 (National Defense Authorization Act 2018) and the Small Business Act (15 U.S.C. 638), the DARPA Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are designed to provide small, high-tech businesses and academic institutions the opportunity to propose radical, innovative, high-risk approaches to address existing and emerging national security threats; thereby supporting DARPA's overall strategy to enable fundamental discoveries and technological breakthroughs that provide new military capabilities.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	0.000	0.000	0.000	-	0.000
Current President's Budget	94.860	0.000	0.000	-	0.000
Total Adjustments	94.860	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	94.860	0.000			

Change Summary Explanation

FY 2017: Increase reflects the SBIR/STTR transfer.
FY 2018: N/A
FY 2019: N/A

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Small Business Innovation Research	94.860	-	-
Description: The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605502E / *SMALL BUSINESS INNOVATION RESEARCH*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
designed to provide small, high-tech businesses and academic institutions the opportunity to propose radical, innovative, high-risk approaches to address existing and emerging national security threats; thereby supporting DARPA's overall strategy to enable fundamental discoveries and technological breakthroughs that provide new military capabilities.			
Accomplishments/Planned Programs Subtotals	94.860	-	-

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Not applicable.

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605898E / *MANAGEMENT HQ - R&D*

COST ($ in Millions)	Prior Years	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total	FY 2020	FY 2021	FY 2022	FY 2023	Cost To Complete	Total Cost
Total Program Element	-	3.859	14.017	13.643	-	13.643	13.498	13.583	13.664	13.666	-	-
MH-01: *MANAGEMENT HQ - R&D*	-	3.859	14.017	13.643	-	13.643	13.498	13.583	13.664	13.666	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Management HQ - R&D Program Element provides funding for the administrative support costs of the Defense Advanced Research Projects Agency. This project provides funding for DARPA Management Headquarters Activities (MHA). The funds provide personnel compensation for management headquarters civilians as well as associated travel and support contract costs. Mission support costs are reflected in PE 0605001E, Project MST-01.

B. Program Change Summary ($ in Millions)	FY 2017	FY 2018	FY 2019 Base	FY 2019 OCO	FY 2019 Total
Previous President's Budget	4.759	14.017	13.493	-	13.493
Current President's Budget	3.859	14.017	13.643	-	13.643
Total Adjustments	-0.900	0.000	0.150	-	0.150
• 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	-0.900	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• TotalOtherAdjustments	-	-	0.150	-	0.150

Change Summary Explanation

FY 2017: Decrease reflects reprogrammings.
FY 2018: N/A
FY 2019: Increase reflects minor repricing.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
Title: Management Headquarters	3.859	14.017	13.643
Description: Management Headquarters			

Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Defense Advanced Research Projects Agency	Date: February 2018
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605898E / *MANAGEMENT HQ - R&D*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2017	FY 2018	FY 2019
FY 2018 Plans: - Fund management headquarters civilian salaries, benefits, travel and support contract costs. ***FY 2019 Plans:*** - Fund management headquarters civilian salaries, benefits, travel and support contract costs. ***FY 2018 to FY 2019 Increase/Decrease Statement:*** The FY 2019 decrease reflects MHA civilian personnel and service support contract efficiencies.			
Accomplishments/Planned Programs Subtotals	3.859	14.017	13.643

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.