Department of Defense
Fiscal Year (FY) 2018 Budget Estimates

May 2017

Defense Advanced Research Projects Agency

Defense-Wide Justification Book Volume 1 of 1

Research, Development, Test & Evaluation, Defense-Wide

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FY 2018 President's Budget Request
Exhibit R-1 FY 2018 President's Budget Request
Total Obligational Authority
(Dollars in Thousands)

27 Apr 2017

Appropriation	FY 2016 Base + OCO	FY 2017 PB Request with CR Adj Base	FY 2017 Total PB Requests* with CR Adj Base	FY 2017 PB Request with CR Adj OCO	FY 2017 Total PB Requests* with CR Adj OCO	FY 2017 Less Enacted Div B P.L.114-254** OCO	FY 2017 Remaining Req with CR Adj OCO
Research, Development, Test & Eval, DW	2,868,281	2,973,036	2,973,036				
Total Research, Development, Test & Evaluation	2,868,281	2,973,036	2,973,036				

Department of Defense
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Research, Development, Test & Eval, DW	2,973,036	2,973,036		2,973,036	3,170,390		3,170,390
Total Research, Development, Test & Evaluation	2,973,036	2,973,036		2,973,036	3,170,390		3,170,390

Department of Defense
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Summary Recap of Budget Activities	FY 2016 Base + OCO	FY 2017 PB Request with CR Adj Base	FY 2017 Total PB Requests* with CR Adj Base	FY 2017 PB Request with CR Adj OCO	FY 2017 Total PB Requests* with CR Adj OCO	FY 2017 Less Enacted Div B P.L.114-254** OCO	FY 2017 Remaining Req with CR Adj OCO
Basic Research	369,943	420,088	420,088				
Applied Research	1,127,989	1,246,308	1,246,308				
Advanced Technology Development	1,209,718	1,232,637	1,232,637				
Management Support	160,631	74,003	74,003				
Total Research, Development, Test & Evaluation	2,868,281	2,973,036	2,973,036				
Summary Recap of FYDP Programs							
Research and Development	2,868,281	2,973,036	2,973,036				
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Basic Research	420,088	420,088		420,088	475,473		475,473
Applied Research	1,246,308	1,246,308		1,246,308	1,378,821		1,378,821
Advanced Technology Development	1,232,637	1,232,637		1,232,637	1,238,310		1,238,310
Management Support	74,003	74,003		74,003	77,786		77,786
Total Research, Development, Test & Evaluation	2,973,036	2,973,036		2,973,036	3,170,390		3,170,390
Summary Recap of FYDP Programs							
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Defense Advanced Research Projects Agency	2,868,281	2,973,036	2,973,036				
Total Research, Development, Test & Evaluation	2,868,281	2,973,036	2,973,036				

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Total Research, Development, Test & Evaluation	2,973,036	2,973,036		2,973,036	3,170,390		3,170,390

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

Line No	Program Element Number	Item	Act	FY 2016 Base + OCO	FY 2017 PB Request with CR Adj Base	FY 2017 Total PB Requests* with CR Adj Base	FY 2017 PB Request with CR Adj OCO	FY 2017 Total PB Requests* with CR Adj OCO	FY 2017 Less Enacted Div B P.L.114-254** OCO	FY 2017 Remaining Req with CR Adj OCO	Sec
2	0601101E	Defense Research Sciences	01	317,207	362,297	362,297					U
4	0601117E	Basic Operational Medical Research Science	01	52,736	57,791	57,791					U
	Basic Research			369,943	420,088	420,088					
9	0602115E	Biomedical Technology	02	120,512	115,213	115,213					U
13	0602303E	Information & Communications Technology	02	331,720	353,635	353,635					U
14	0602383E	Biological Warfare Defense	02	24,682	21,250	21,250					U
17	0602702E	Tactical Technology	02	289,371	313,843	313,843					U
18	0602715E	Materials and Biological Technology	02	193,471	220,456	220,456					U
19	0602716E	Electronics Technology	02	168,233	221,911	221,911					U
	Applied Research			1,127,989	1,246,308	1,246,308					
35	0603286E	Advanced Aerospace Systems	03	165,764	182,327	182,327					U
36	0603287E	Space Programs and Technology	03	120,642	175,240	175,240					U
56	0603739E	Advanced Electronics Technologies	03	78,984	49,807	49,807					U
57	0603760E	Command, Control and Communications Systems	03	201,635	155,081	155,081					U
58	0603766E	Network-Centric Warfare Technology	03	411,060	428,894	428,894					U
59	0603767E	Sensor Technology	03	231,633	241,288	241,288					U
	Advanced Technology Development			1,209,718	1,232,637	1,232,637					
142	0605001E	Mission Support	06		69,244	69,244					U
157	0605502E	Small Business Innovative Research	06	89,060							U

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

Line No	Program Element Number	Item	Act	FY 2017 Total PB Requests** with CR Adj Base+OCO+SAA	FY 2017 Total PB Requests* with CR Adj Base + OCO	FY 2017 Less Enacted Div B P.L.114-254** OCO	FY 2017 Remaining Req with CR Adj Base + OCO	FY 2018 Base	FY 2018 OCO	FY 2018 Total	Sec
2	0601101E	Defense Research Sciences	01	362,297	362,297		362,297	432,347		432,347	U
4	0601117E	Basic Operational Medical Research Science	01	57,791	57,791		57,791	43,126		43,126	U
		Basic Research		420,088	420,088		420,088	475,473		475,473	
9	0602115E	Biomedical Technology	02	115,213	115,213		115,213	109,360		109,360	U
13	0602303E	Information & Communications Technology	02	353,635	353,635		353,635	392,784		392,784	U
14	0602383E	Biological Warfare Defense	02	21,250	21,250		21,250	13,014		13,014	U
17	0602702E	Tactical Technology	02	313,843	313,843		313,843	343,776		343,776	U
18	0602715E	Materials and Biological Technology	02	220,456	220,456		220,456	224,440		224,440	U
19	0602716E	Electronics Technology	02	221,911	221,911		221,911	295,447		295,447	U
		Applied Research		1,246,308	1,246,308		1,246,308	1,378,821		1,378,821	
35	0603286E	Advanced Aerospace Systems	03	182,327	182,327		182,327	155,406		155,406	U
36	0603287E	Space Programs and Technology	03	175,240	175,240		175,240	247,435		247,435	U
56	0603739E	Advanced Electronics Technologies	03	49,807	49,807		49,807	79,173		79,173	U
57	0603760E	Command, Control and Communications Systems	03	155,081	155,081		155,081	106,787		106,787	U
58	0603766E	Network-Centric Warfare Technology	03	428,894	428,894		428,894	439,386		439,386	U
59	0603767E	Sensor Technology	03	241,288	241,288		241,288	210,123		210,123	U
		Advanced Technology Development		1,232,637	1,232,637		1,232,637	1,238,310		1,238,310	
142	0605001E	Mission Support	06	69,244	69,244		69,244	63,769		63,769	U
157	0605502E	Small Business Innovative Research	06								U

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166	0605898E	Management HQ - R&D	06	71,571	4,759	4,759					U
		Management Support		160,631	74,003	74,003					
Total Research, Development, Test & Eval, DW				2,868,281	2,973,036	2,973,036					

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166	0605898E	Management HQ - R&D	06	4,759	4,759		4,759	14,017		14,017	U
		Management Support		74,003	74,003		74,003	77,786		77,786	
Total Research, Development, Test & Eval, DW				2,973,036	2,973,036		2,973,036	3,170,390		3,170,390	

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157	0605502E	Small Business Innovative Research	06	89,060							U

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166	0605898E	Management HQ - R&D	06	4,759	4,759		4,759	14,017		14,017	U
	Management Support			74,003	74,003		74,003	77,786		77,786	
Total Defense Advanced Research Projects Agency				2,973,036	2,973,036		2,973,036	3,170,390		3,170,390	

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

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

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Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	317.207	362.297	432.347	-	432.347	410.178	405.698	395.466	412.498	-	-
BLS-01: *BIO/INFO/MICRO SCIENCES*	-	3.000	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
CCS-02: *MATH AND COMPUTER SCIENCES*	-	142.533	149.065	169.069	-	169.069	186.160	185.643	180.196	186.536	-	-
CYS-01: *CYBER SCIENCES*	-	45.431	45.000	41.176	-	41.176	22.355	10.000	10.000	20.000	-	-
ES-01: *ELECTRONIC SCIENCES*	-	36.806	49.553	86.626	-	86.626	69.546	52.883	52.883	52.883	-	-
MS-01: *MATERIALS SCIENCES*	-	57.890	65.609	75.599	-	75.599	63.780	83.830	85.138	85.138	-	-
TRS-01: *TRANSFORMATIVE SCIENCES*	-	31.547	53.070	59.877	-	59.877	68.337	73.342	67.249	67.941	-	-

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, biological and materials sciences.

The Bio/Info/Micro Sciences project investigated and developed the intersections of biology, information technology and micro/physical systems to exploit important technological advances and leverage fundamental discoveries for the development of new technologies, techniques, and systems of interest to the DoD. This research is critical to the development of improved training and cognitive rehabilitation. Programs in this project drew upon the information 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. This project developed the basic research tools in biology that are unique to the application of biological-based solutions to critical Defense problems.

The Math and Computer Sciences project supports scientific study and experimentation on new computational algorithms, models, and mechanisms in support of long-term national security requirements. The project is exploring novel means of leveraging computer capabilities, including: practical, logical, heuristic, and automated reasoning by machines; enhanced human-to-computer and computer-to-computer interaction technologies; innovative approaches to the composition of software; innovative computer architectures; mathematical programs and their potential for defense applications; and new learning mechanisms for systematically upgrading and improving these capabilities. Promising techniques will transition to both technology development and system-level projects.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 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, and mission-critical information systems 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. Promising research results will be transitioned to both technology development and system-level projects.

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 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.

B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	333.119	362.297	361.151	-	361.151
Current President's Budget	317.207	362.297	432.347	-	432.347
Total Adjustments	-15.912	0.000	71.196	-	71.196
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-5.304	0.000			
• SBIR/STTR Transfer	-10.608	0.000			
• TotalOtherAdjustments	-	-	71.196	-	71.196

Change Summary Explanation

FY 2016: Decrease reflects reprogrammings and the SBIR/STTR transfer.

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FY 2017: N/A

FY 2018: Increase reflects expanded focus in Math and Computer sciences, Cyber, Electronics (including Beyond Scaling programs), Materials and Transformative sciences.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) BLS-01 / *BIO/INFO/MICRO SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
BLS-01: *BIO/INFO/MICRO SCIENCES*	-	3.000	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

This project investigated and developed the intersections of biology, information technology and micro/physical systems to exploit important technological advances and leverage fundamental discoveries for the development of new technologies, techniques, and systems of interest to the DoD. This research is critical to the development of improved training and cognitive rehabilitation. Programs in this project drew upon the information 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. This project developed the basic research tools in biology that are unique to the application of biological-based solutions to critical Defense problems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Quantitative Models of the Brain	3.000	-	-
Description: The Quantitative Models of the Brain program established a functional mathematical basis on which to build future advances in cognitive neuroscience, computing capability, and signal processing across the DoD. An important focus of this program was determining how information is stored and recalled in the brain and other DoD-relevant signals, developing predictive, quantitative models of learning, memory, and measurement. Using this understanding, the program developed powerful new symbolic computational capabilities for the DoD in a mathematical system that has provided the ability to understand complex and evolving signals and tasks while decreasing software and hardware requirements and other measurement resources. This included a comprehensive mathematical theory to extract and leverage information in signals at multiple acquisition levels that would fundamentally generalize compressive sensing for multi-dimensional sources beyond domains typically used. New insights related to signal priors, task priors, and adaptation have enabled these advances. This program further exploited advances in the understanding and modeling of brain activity and organization to improve training of individuals as well as identify new therapies for cognitive rehabilitation (e.g., Traumatic Brain Injury (TBI), Post Traumatic Stress Disorder (PTSD)). Critical to success was the ability to detect cellular and network-level changes produced in the brain during the formation of new, hierarchically organized memories and memory classes, and to correlate those changes with memory function of animals during performance of behavioral tasks.			
FY 2016 Accomplishments: - Built hippocampal-neocortical model of stimulation-based memory enhancement. - Developed and applied a new set of classification models for the prediction of behavioral outcomes from the spatio-temporal patterns of electrophysiological recordings in the hippocampus.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Developed initial computational model of integrated neural, physiological, and environmental effects in neural replay, skill acquisition, and subsequent memory recall.			
Accomplishments/Planned Programs Subtotals	3.000	-	-

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
CCS-02: *MATH AND COMPUTER SCIENCES*	-	142.533	149.065	169.069	-	169.069	186.160	185.643	180.196	186.536	-	-

A. Mission Description and Budget Item Justification

The Math and Computer Sciences project supports scientific study and experimentation on new computational algorithms, models, and mechanisms in support of long-term national security requirements. The project is exploring novel means of leveraging computer capabilities, including: practical, logical, heuristic, and automated reasoning by machines; enhanced human-to-computer and computer-to-computer interaction technologies; innovative approaches to the composition of software; innovative computer architectures; mathematical programs and their potential for defense applications; and new learning mechanisms for systematically upgrading and improving these capabilities. Promising techniques will transition to both technology development and system-level projects.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Building Resource Adaptive Software from Specifications (BRASS)	17.343	17.419	17.450

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 process 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 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 2016 Accomplishments:

- Initiated the integration of specifications within an operational environment to monitor resource changes and trigger signals when resource invariants are violated.
- Formulated compile-time and runtime transformations that ensure survivable operation in the face of unexpected environment changes.
- Designed validation tools that certify that transformed applications satisfy specification assumptions in the context of new operating environment guarantees.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Developed platform-specific challenge problems from military domains. ***FY 2017 Plans:*** - Develop new forms of resource-sensitive specifications capable of defining complex resource changes involving both physical and logical resources. - Build compiler and runtime infrastructure that are sensitive to ecosystem evolution. - Incorporate monitoring tools capable of runtime verification of adaptive program transformations without incurring significant execution overhead. - Evaluate the effectiveness of the developed systems in collaboration with potential transition partners. ***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 ecosystem changes. - Implement program synthesis tools that automatically generate new programs functionally 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.			
Title: Young Faculty Award (YFA)	16.440	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 2016 Accomplishments:*** - Awarded new FY 2016 grants for new two-year research efforts across the topic areas which established a new set of appropriate technologies to solve current DoD problems. - Continued FY 2015 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.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Awarded Director's Fellowships for top FY 2014 participants. During this additional year of funding, researchers will refine their technology further and align to DoD needs. ***FY 2017 Plans:*** - Award new FY 2017 grants for new two-year research efforts across the topic areas, establishing a new set of appropriate technologies to solve current DoD problems. - Continue FY 2016 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 2015 participants. During this additional year of funding, researchers will refine their technology further and align to 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. During this additional year of funding, researchers will refine their technology further and align to DoD needs.			
Title: Human Social Systems ***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 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. This thrust is an aggregation of programs previously contained in Knowledge Representation. ***FY 2016 Accomplishments:*** - Began to explore novel experimental approaches for repeatable and replicable testing of social simulation representation and modeling tools for understanding social behavioral outcomes. ***FY 2017 Plans:***	2.500	7.640	16.400

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Develop new methods and tools to enhance the reproducibility of experimental results to accelerate discovery in research and modeling of human social behaviors. - Demonstrate the utility of new networked data collection, mathematical, and computational modeling tools for representing complex social interactions. - Begin to initiate the development of new simulation and computational modeling tools for representing complex social interactions. ***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.			
Title: Communicating With Computers (CWC)	13.576	15.213	14.966
Description: The Communicating With Computers (CWC) program is advancing the state-of-the-art in human-computer interaction by enabling computers to comprehend language, gesture, facial expression and other communicative modalities in context. Human language is inherently ambiguous and so humans depend strongly on perception of the physical world and context to make language comprehensible. CWC aims to 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 in the physical world. CWC will also work to 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 2016 Accomplishments:*** - Explored methods for determining whether transmitted communications have been successfully received, and if not, what additional communications would most likely result in success. - Implemented initial representations for the physical world and developed first versions of connectors to large-scale knowledge bases to enable visual-language synergies. - Began construction of a universal corpus of elementary composable ideas that in combination can convey the meaning of most communications. ***FY 2017 Plans:*** - Develop a capability to enable computer inputs using gesture, facial expression and other communicative modalities.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Implement initial techniques for confirming that communications have been successfully received and extrapolate potentially missing information. - Demonstrate human-machine communication and collaboration on a physical problem solving task. ***FY 2018 Plans:*** - Demonstrate human-machine communication on a problem solving task in which humans and machines collaborate to explain how gene and protein interactions cause phenotypic effects. - Demonstrate learning of communication principles and evaluate through the biocuration use case. - Demonstrate that increased cognitive bandwidth of communication enables machines to be full collaborators with humans, not merely tools, in solving problems.			
Title: Mining and Understanding Software Enclaves (MUSE) ***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 techniques will apply 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. MUSE frameworks will enable robust execution of large-scale and data-intensive computations. 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 2016 Accomplishments:*** - Implemented scalable mining algorithms that allow the ingestion and analysis of tens of millions of lines of open-source software. - Integrated machine learning algorithms that direct and assimilate mining activities on analysis artifacts. - Evaluated component-level synthesis techniques to build implementations for complex self-contained algorithms. - Demonstrated the effectiveness of the developed systems. ***FY 2017 Plans:*** - Extend the size of the ingested corpus by orders of magnitude to deal with increasingly more complex program repair and synthesis tasks. - Apply deep learning algorithms on complex graph structures produced by corpus mining to discover latent relationships among corpus elements.	12.069	13.000	13.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Exploit techniques such as program sketching, user-guided feedback, and specification-driven analysis to automatically construct implementations of complex protocols from discovered specifications. - Evaluate the effectiveness of the developed systems in collaboration with potential transition partners. ***FY 2018 Plans:*** - Develop statistical database technologies for scalable feature exploration and mining of the corpus. - Apply machine learning concepts to predict, repair, and synthesize program properties and structures from purely black-box observations. - Explore the use of both static and dynamic program analyses to discover software anomalies and prescribe program repair recipes. - Use natural language processing techniques to discover semantic properties of code from information sources such as developer documentation, message boards, tutorial material, question-and-answer forums, and blog entries.			
Title: Advanced Tools for Modeling and Simulation	7.678	12.376	10.000
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. This thrust is an aggregation of programs previously contained in Quantifying Uncertainty in Physical Systems and Knowledge Representation. ***FY 2016 Accomplishments:*** - Began to explore novel mathematical representations that can accommodate the possibilities of new materials for enabling simultaneous design exploration and optimization. - Began to explore novel interfaces for computational design tools that incorporate material structures and physics to enable simultaneous design exploration and optimization under uncertainty. - Began to develop a quantitative framework for analyzing and optimizing human interactions with engineered components in collaborative networks consisting of human-machine systems and systems-of-systems. - Initiated development of novel computational frameworks for modeling non-linear effects in complex systems.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Designed an open source, benchmarking framework for modeling non-linear effects in complex systems across multiple scales. ***FY 2017 Plans:*** - Demonstrate the use of novel representations spanning multiple orders of resolution to capture material architectures at the meso-scale in conjunction with macro-scale shapes. - Develop techniques to enable efficient computation of integral and differential properties in designs that consider inherent variability. - Demonstrate the feasibility to exploit the computing capacity offered by nonlinear systems to simulate nonlinear dynamical systems. - Start to develop analog computing substrates for efficiently simulating systems governed by complex non-linear phenomena. - Formulate mathematical frameworks to articulate and analyze general machine learning problems and associated limits. ***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 construct 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.			
Title: Quantifying Uncertainty in Physical Systems ***Description:*** The Quantifying Uncertainty in Physical Systems thrust will create the basic mathematics needed to efficiently quantify, propagate and manage multiple sources of (parametric and model) uncertainty to make accurate predictions about and also design stochastic, complex DoD systems. In particular, this will include new approaches for scaling Uncertainty Quantification (UQ) methods to multiscale/multiphysics DoD systems; techniques for correcting model-form uncertainty and for understanding rare events; and new methods for decision making, control, and design under uncertain conditions. ***FY 2016 Accomplishments:*** - Developed scalable approximation methods with provable error bounds for optimization in the presence of high dimensional uncertain parameters.	15.380	9.000	5.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Developed scalable Bayesian inference algorithms for inverse methods with orders of magnitude speed-up incorporating the known physical properties of DoD systems. - Derived proofs and theoretical treatment of rare event detection algorithms within risk-based optimization framework. ***FY 2017 Plans:*** - Develop new mathematical design techniques for high dimensional, multi-physics problems in the presence of high-dimensional uncertainty. - Initiate design work on a specific DoD multi-fidelity and multi-physics challenge problem. - Develop new multi-fidelity techniques for model error estimation. ***FY 2018 Plans:*** - Develop risk-averse stochastic optimization methods to address a complex multi-physics challenge problem and implement the scalable UQ methods as well as the model error estimates in the optimization framework. - Demonstrate the efficacy of UQ methodologies in a final stochastic design problem.			
Title: Big Mechanism	19.494	12.116	4.353
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 yet predictive, ideally causal, models from massive volumes of diverse data generated by human actors, physical sensors and networked devices. Current modeling approaches are heavily reliant on human insight and expertise, but the complexity of these models is growing exponentially and has now, or will soon, exceed the capacity for human comprehension. Big Mechanism will create technologies to extract and normalize information for incorporation in flexible knowledge bases readily adapted to novel problem scenarios; powerful reasoning engines that can infer general rules from a collection of observations, apply general rules to specific instances, and generate (and compute the likelihood of) the most plausible explanations for a sequence of events; and knowledge synthesis techniques to derive abstract principles and/or create models of extreme complexity consistent with huge volumes of data. Big Mechanism applications will accommodate an operator-in-the-loop by accepting questions posed in human natural language, providing drill-down to reveal the basis for an answer, taking user inputs to improve/correct derived associations, weightings and conclusions, and querying the operator to clarify ambiguities and reconcile detected inconsistencies. Big Mechanism techniques will integrate burgeoning data into causal models and explore these models for precise interventions. The program has adopted cancer modeling as an initial focus because the availability of experimental data and the complexity of the problems are representative of challenges facing the DoD in areas such as cyber attribution and open-source intelligence. ***FY 2016 Accomplishments:*** - Demonstrated automated reading of technical literature to extract information and construct models.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Automated testing of machine-generated hypotheses. - Created new modes for visualizing and exploring models of huge scope that in their entirety exceed human cognitive capabilities. - Demonstrated prototype technologies in production mode by identifying drug targets and drugs for specific classes of cancer. ***FY 2017 Plans:*** - Create interfaces and tools to support a web-based resource of machine-curated cancer pathways. - Create utilities to add genomic information to machine-curated cancer pathways. - Publish a high-fidelity simulation of the Ras cancer pathway. ***FY 2018 Plans:*** - Apply techniques to other cancer classes and extend techniques to additional problem domains. - Develop and implement scalable algorithms that reveal causality networks in large, complex, heterogeneous datasets. - Develop empirical algorithms for early indications and/or tracking of medical conditions such as neurological impairment, musculoskeletal injury, and cardio-vascular issues.			
Title: Knowledge Representation	11.545	8.784	3.000
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 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 2016 Accomplishments:*** - Demonstrated data input and information extraction within the previously developed mathematical knowledge framework. - Incorporated domain-specific prior knowledge, such as computational models, into the mathematical knowledge framework. - Demonstrated the integration of datasets and prior domain knowledge in one or more scientific and engineering use cases. ***FY 2017 Plans:*** - Demonstrate hypothesis generation and steering using newly developed knowledge representation tools on one or more scientific and engineering use cases.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Analyze and optimize knowledge representation system performance in terms of scalability for inference and knowledge ingestion. ***FY 2018 Plans:*** - Develop and test mathematical tools for hypothesis generation testing and model validation. - Demonstrate integrated system that ingests and registers data and knowledge, allows query and recall as well as hypothesis generation and steering, and validated analysis on multiple domains.			
Title: Synergistic Discovery and Design (SD2) ***Description:*** The Synergistic Discovery and Design (SD2) program will develop 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, automobiles, and integrated circuits. In contrast, robust design remains elusive in domains such as synthetic biology, neuro-computation, and polymer chemistry due to the lack of high-fidelity models. The SD2 program will develop tools to enable robust design despite the lack of complete scientific models. This will involve 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. The program will adopt synthetic biology as the primary application domain. Alternative domains of interest include chemistry, material science, and neuro-computation. SD2 builds on techniques being developed under the Probabilistic Programming for Advancing Machine Learning program. ***FY 2017 Plans:*** - Establish data ingest, indexing, and sharing techniques to enable collaborative analysis of experimental data at scale. - Develop algorithms that reveal nuanced features in raw experimental data to inform the development of new scientific principles. - Develop a computer-readable protocol-capture language to enable assembly of high-quality, integrated experimental data from cellular biochemistry experiments conducted in disparate labs. ***FY 2018 Plans:*** - Improve accuracy of computational techniques that extract scientific knowledge directly from experimental data. - Establish experimental planning tools to facilitate iterative feedback between knowledge-discovery and design. - Develop automated design tools that reduce the impact of variability in experimental conditions across laboratory environments.	-	13.000	21.000
Title: World Modelers ***Description:*** The World Modelers program builds on techniques developed in the Big Mechanism program to create 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, including war. Water and food	-	10.863	16.800

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
security are application domains of particular interest, as persistent drought may cause crops to fail, with consequential migration and conflict between peoples. The World Modelers program will develop the capability to model regional and global systems to generate timely indications and warnings with techniques for automating the creation, maintenance, and validation of large-scale integrated models using primary literature (e.g., news and analyst reports, journal articles) as a structuring mechanism and government and commercial data (e.g., remote sensing imagery, commodities futures prices) as quantitative inputs. 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 2017 Plans:*** - Propose approaches for integrating numerical and semantic techniques in quantitative and qualitative models. - Initiate construction of large-scale data sets for validating models of challenges such as food security and human migration. ***FY 2018 Plans:*** - Implement automated machine reading and learning techniques for updating large-scale models using primary literature and government and commercial data. - Demonstrate an initial capability to model natural and human-mediated perturbations having the potential to impact theater security such as water shortages, crop failures, and hoarding of critical resources. - Test models of regional and global phenomena and initiate formulation of theory to understand model accuracy.			
Title: Complex Hybrid Systems ***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 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. This thrust is an aggregation of programs previously contained in Quantifying Uncertainty in Physical Systems and Knowledge Representation. ***FY 2017 Plans:*** - Demonstrate the impact of team composition parameters on human-machine system performance. - Begin the development of an experimental environment that can test the impact of variation of human-machine system configuration. ***FY 2018 Plans:***	-	3.346	14.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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.			
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. 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 could impact a broad array of military applications that require processing and understanding data, particularly in real world 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 dataset. - Develop description of how new biological mechanism will be proven and measured in software, including preliminary specifications of test data.	-	-	16.100
Title: Probabilistic Programming for Advancing Machine Learning (PPAML) ***Description:*** The Probabilistic Programming for Advancing Machine Learning (PPAML) program is creating an advanced computer programming capability that greatly facilitates the construction of new machine learning applications in a wide range of domains. This capability will increase the number of people who can effectively contribute, make experts more productive, and enable 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 would convert into efficient applications. PPAML technologies	11.188	9.308	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
will be 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. ***FY 2016 Accomplishments:*** - Demonstrated advanced probabilistic abstractions, inference techniques, and implementations. - Enriched probabilistic programming systems with stronger probabilistic abstractions and improved integration with solvers and inference engines. - Extended the compilation back end of a probabilistic programming system with support for new inference techniques. - Evaluated the performance of each probabilistic programming system both in terms of the quality of the results and the levels of resources required. ***FY 2017 Plans:*** - Integrate probabilistic systems within domain-specific contexts to provide tailored functionality. - Build new probabilistic solvers that incorporate state-of-the-art machine learning algorithms that operate at scales at least one order of magnitude greater than currently feasible. - Work with domain experts and transition partners to apply probabilistic programming systems in domains that have military relevance.			
Title: Unconventional Processing of Signals for Intelligent Data Exploitation (UPSIDE) ***Description:*** The Unconventional Processing of Signals for Intelligent Data Exploitation (UPSIDE) program created a new generation of computing structures, enabling revolutionary advances in real-time sensor data analysis. To demonstrate the impact of this advance, the program improved the performance and power efficiency of detecting and tracking objects in video streams. Today, computer-based object detection and tracking requires matching an object of interest to its high-precision digital representation, which is an inherently power-hungry process. UPSIDE instead employed an approach known as approximate computing which operates very efficiently on both semiconductor-based electronic devices and emerging alternative devices without sacrificing accuracy. UPSIDE demonstrated five to seven orders of magnitude improvement in the power efficiency and performance of real-time sensor data analysis. The UPSIDE computing approach was benchmarked against a DoD-relevant image processing pipeline to verify gains in both throughput and power efficiency. ***FY 2016 Accomplishments:*** - Built and completed a test bed for evaluating semiconductor-based electronic devices that perform object identification and tracking. - Established a digital baseline of power consumption, performance, and accuracy for identifying and tracking objects in a surveillance video.	15.320	-	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrated significant power consumption and performance improvements for a semiconductor-based UPSIDE chip, relative to the digital baseline for object identification and tracking applications. - Simulated the potential for conducting image processing applications on non-semiconductor-based emerging devices. The projections suggested a 1000x improvement in performance and 10,000x reduction in power consumption with no loss of accuracy compared to image processing on conventional devices.			
Accomplishments/Planned Programs Subtotals	142.533	149.065	169.069

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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COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
CYS-01: *CYBER SCIENCES*	-	45.431	45.000	41.176	-	41.176	22.355	10.000	10.000	20.000	-	-

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, and mission-critical information systems 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. Promising research results will be transitioned to both technology development and system-level projects.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Transparent Computing	19.049	18.321	16.648

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 obscures 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 2016 Accomplishments:
- Implemented adaptive security policy schemes in software prototypes and performed initial assessments in simulated laboratory and cloud environments.
- Developed and implemented behavioral attestation techniques in software prototypes scalable to big data applications.
- Developed and implemented causal dependency tracking across software/hardware abstraction layers.

FY 2017 Plans:
- Develop provenance graph analytics algorithms for clustering, role discovery, anomaly detection, root cause analysis and extrapolation.
- Develop integrated provenance tracking mechanisms and a forensic analysis capability for a single system with browser and apps.
- Conduct an evaluation against a compromised browser based on an operational APT scenario.

FY 2018 Plans:

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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 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.			
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 now cyber adversaries must find 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 attacks in the software upon which the U.S. government, military, and economy depend. ***FY 2016 Accomplishments:*** - Defined the formal semantics of runtime environments in which vulnerable software runs, and encoded the semantics in a form consumable by automated analysis tools. - Produced initial analysis tools that reason about data and control flow paths in computer programs, identified inputs adversaries can use to mount algorithmic complexity attacks, and identified outputs that adversaries can use to mount side channel attacks. - Performed a competitive experiment using prototype analysis tools to find algorithmic complexity vulnerabilities and side channel attacks in a corpus of challenge programs. ***FY 2017 Plans:*** - Develop and demonstrate more reliable detection of algorithmic resource usage vulnerabilities by incorporating fine-grained semantics of the underlying run-time environment and operating system. - Develop and evaluate tools that identify dangerous conditions, either inputs adversaries could use to mount algorithmic complexity attacks or outputs that adversaries could use to mount side channel attacks. - Identify potential users with a need to demonstrate the absence of vulnerabilities to algorithmic complexity and side channel attacks in mission critical systems. ***FY 2018 Plans:*** - Develop and implement methods for remediating algorithmic resource usage vulnerabilities by automatically generating patches. - 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 in a best-of-breed prototype.	15.078	16.360	14.573

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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.			
Title: SafeWare	11.304	10.319	9.955
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.), which 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 1970's. 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 re-tool its mathematical foundations to move it towards becoming practical and efficient. ***FY 2016 Accomplishments:*** - Explored potentially powerful new primitives for cryptographic program obfuscation such as multilinear maps. - Developed alternate models of obfuscation for specialized aggressor models, and optimized domain-specific algorithms for obfuscation efficiency. - Created an evaluation platform/environment capable of quantifying runtime efficiency and cryptographic security of the obfuscation algorithms and software implementations, and initiated assessments. ***FY 2017 Plans:*** - Based on initial assessment results, develop new obfuscation theory and implementations better suited to codes encountered in operational systems. - Use adversarial techniques to identify side channel vulnerabilities in the obfuscation algorithms and software implementations. - Explore specific obfuscation features and capabilities that address use cases relevant to sensitive systems and missions. ***FY 2018 Plans:*** - Develop demonstrations of obfuscation protocols with provable security properties and quantifiable security levels for less simple computational or algorithmic processes. - Create modular approaches to obfuscation in order to be able to restrict obfuscation to the most sensitive parts of computational or algorithmic processes only. - Develop fundamental re-constructions of classic cryptographic protocols using obfuscation as a basic resource for computational security.			
Accomplishments/Planned Programs Subtotals	45.431	45.000	41.176

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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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
ES-01: *ELECTRONIC SCIENCES*	-	36.806	49.553	86.626	-	86.626	69.546	52.883	52.883	52.883	-	-

A. Mission Description and Budget Item Justification

This 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Direct On-Chip Digital Optical Synthesis (DODOS)	6.500	7.000	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.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
FY 2016 Accomplishments: - Demonstrated compact low-threshold octave-spanning combs suitable for DODOS integration. - Demonstrated methods for stabilizing the phase coherence of a microresonator comb across a broad optical bandwidth. - Successfully developed Complementary Metal-Oxide Semiconductor-compatible materials for frequency stabilization of optical combs, facilitating integration with critical photonic components. - Characterized the output of a slave laser locked to a stabilized microresonator comb and evaluated the performance relative to promising DoD applications for DODOS technology. ***FY 2017 Plans:*** - Develop and demonstrate efficient electronic control algorithms to accurately sweep the slave laser across 50 nanometers (nm) of comb bandwidth. - Investigate methods to further reduce threshold of self-referenced combs. - Design and implement on-chip photonic components to mitigate issues associated with excess phase noise, cross talk, back reflection and isolation to achieve integrated DODOS system performance metrics. ***FY 2018 Plans:*** - Develop and implement techniques to improve the laser frequency tuning speed and tuning accuracy using co-integrated electronic and photonic components. - Complete analysis to validate the feasibility of utilizing DODOS technology for a proposed DoD-relevant application.			
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC)	4.000	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 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 2016 Accomplishments:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Researched high-fidelity, three-dimensional, multi-physics, numerically efficient modeling and simulation techniques that lead to first-pass design success. - Investigated advanced manufacturing methods such as Selective Laser Sintering (SLS) and other additive manufacturing methods for beam-wave interaction circuits and other tube components. ***FY 2017 Plans:*** - Investigate a more complete fundamental understanding of electron emission enabling the a priori design of high current-density, long-life cathodes. - Design novel wideband and high-power beam-wave interaction structures. ***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.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM)	4.306	5.008	5.200
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 2016 Accomplishments:*** - Developed preliminary models to simulate novel chip-scale inertial sensors such as optical waveguide gyroscopes and optically interrogated MEMS gyroscopes and accelerometers. - Developed MEMS and photonic integration processes demonstrating novel approaches to inertial sensing.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Developed an experimental test setup to support short-loop experiments for novel photonic-MEMS gyroscopes and accelerometers. ***FY 2017 Plans:*** - Demonstrate laboratory prototype photonic-MEMS inertial sensors with navigation-grade accuracy and stability. - Optimize novel optical and MEMS inertial sensor designs through modeling and simulation after completing initial experimental characterization. ***FY 2018 Plans:*** - Integrate component technology and demonstrate photonic-MEMS inertial sensors with beyond-navigation-grade stability and precision. - Test navigation-grade inertial sensor performance robustness to external perturbations such as vibration and shock.			
Title: Signal Processing at RF (SPAR)*	-	8.745	12.000
Description: *Formerly part of Quantum and Materials Basics 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 2017 Plans:*** - Develop theoretical framework and modeling of RF signal processing components for rejecting in-band RF interference. - Design and fabrication of Phase 1 RF signal processing components capable of collectively rejecting uncooperative in-band jamming by 10 fold and cooperative self-interference by 100 fold. - Design and fabrication of Phase 1 RF circulators to provide an additional 30x isolation between the transmitter and receiver ports. ***FY 2018 Plans:*** - Perform measurement of SPAR RF signal processing components meeting Phase 1 performance.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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 10,000x.			
Title: Magnetic Miniaturized and Monolithically Integrated Components (M3IC) ***Description:*** *Formerly part of Quantum and Materials Basics 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 2017 Plans:*** - Demonstrate techniques to grow thick magnetic films on large semiconductor substrates. - Characterize properties and evaluate performance of magnetic films. - Complete modeling tool documentation and demonstrate early concept software. - Define and demonstrate two concepts for innovative component designs that exploit magnetic phenomena. ***FY 2018 Plans:*** - Demonstrate deposition of magnetic films greater than 100 micrometers thick on semiconductor substrates larger than 50 millimeters in diameter, enabling the creation of integrated magnetic components such as circulators with wide bandwidth and low insertion loss. - Characterize properties and evaluate performance of magnetic films. - Prototype integrated magnetic components. - Demonstrate prototype modeling codes with improved accuracy and efficiency. - Demonstrate optimized and miniaturized magnetic components.	-	2.000	10.426
Title: A MEchanically Based Antenna (AMEBA)	-	-	8.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 driven by 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 high performance electret and ferroelectric materials able to support high charge density with low charge leakage rates. - Design and develop electromechanical systems and architectures to realize large scale, high-precision mechanical actuation of magnets and electrically charged materials.			
Title: Joint University Microelectronics Program (JUMP)	-	-	18.000
Description: The Joint University Microelectronics Program (JUMP) program 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 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.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Investigate distributed and centralized computing architectures and subsystems for efficient information extraction, processing, and autonomous control applications.			
Title: Semiconductor Technology Advanced Research Network (STARNet)	18.000	18.000	-
Description: The Semiconductor Technology Advanced Research Network (STARNet) program is a government-industry partnership designed to enable the performance requirements of future sensing, communication, computing, and memory applications. The program sponsors academic research teams focused on technology areas, determined by government and industry experts that impact long-range DoD needs. The sponsored academic research base includes approximately 46 universities, 188 faculty researchers, 628 students, and more than 112 industry associate personnel. Industry provides 60% of program funding, with DARPA providing the remaining 40% of funding. STARNet research is divided into three centers that focus on system issues (design architecture and system design) and three centers that focus on device and materials issues (high-performance and low power devices). As the projects in the device and materials centers mature, they are expected to be utilized by the system centers to enhance improvements in system design and fabrication.			
FY 2016 Accomplishments: - Developed novel materials and steep-turn-on transistor devices and designed proof-of-concept circuit blocks for applications such as lower power imagers, pattern recognition, and scavenging self-powered electronics with extremely low energy-delay product. - Developed voltage-controlled magnetic materials and fabrication techniques to enable power efficient spintronics devices for logic and memory applications. - Developed the scalability of silicon-based computing system concepts to meet the performance, power and cost demands of DoD applications. - Discovered and developed bio- and neuro-inspired information processing architecture framework that approaches the efficiency of brain computation, while aligning well with emerging beyond-complementary metal-oxide semiconductor (CMOS) nanoscale fabrics. - Investigated sensor swarm applications for Defense requirements such as warfighter situational awareness and assessed system characteristics and potential advantages.			
FY 2017 Plans: - Demonstrate low-voltage steep-turn-on transistors beyond traditional CMOS devices and realize the digital, memory, or microwave circuits with extremely low power consumption. - Demonstrate spintronics devices for extremely low-power for logic and non-volatile memory circuits with increased complexity. - Demonstrate heterogeneous and domain accelerated parallel systems by leveraging novel silicon-based computing architecture and integration concepts to enable reliable and secure system designs.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate statistical information processing architectures for in-memory computing and in-sensor computing by CMOS and beyond CMOS prototypes. - Demonstrate swarm-based architecture and prototypes by leveraging localization and energy harvesting capabilities with built-in privacy and security to connect everything and enable urban or theater monitoring applications.			
Title: Beyond Scaling - Materials ***Description:*** The Beyond Scaling - Materials program will investigate new materials to support 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. 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. 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.	-	-	14.000
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-01. ***FY 2018 Plans:***	-	-	7.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate a mechanism for organically adapting hardware based on the moment to moment performance requirements of the software being executed.			
Title: Near Zero Energy RF and Sensor Operations (N-ZERO)	4.000	3.800	-
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. ***FY 2016 Accomplishments:*** - Designed and fabricated near zero power digitization technologies for zero power radio frequency (RF) and physical sensor wake-up circuits. - Designed and fabricated passive and extremely low power analog and digital signal processing technologies for low energy processing of RF and physical sensor signatures. - Designed and fabricated innovative RF and physical sensor designs that perform passive voltage amplification and spectral processing. - Demonstrated a passive RF (900 MHz) transformer with a record voltage gain of 40. - Demonstrated a zero power infrared sensor capable of detecting incident infrared power levels less than 1 micro-watt. - Demonstrated the electronic components needed to amplify and digitize (8-bits) acoustic signals while consuming only 7 nW of power. ***FY 2017 Plans:*** - Experimentally evaluate component technologies. - Design and fabricate improved component technologies enabling the zero power detection and classification of progressively reduced signal level RF and physical sensor signatures.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Investigate transition paths for fundamental technologies into RF communications and physical sensor systems under development in the applied research portion of this project.			
Accomplishments/Planned Programs Subtotals	36.806	49.553	86.626

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
MS-01: *MATERIALS SCIENCES*	-	57.890	65.609	75.599	-	75.599	63.780	83.830	85.138	85.138	-	-

A. Mission Description and Budget Item Justification

This 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 2016	FY 2017	FY 2018
Title: Molecular Systems and Materials Assembly	25.585	27.466	28.813

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, as well as 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 into micro-to-macro-scale objects and devices, as well as fundamental studies of the properties and function of molecular ensembles and systems. This thrust is an aggregation of programs previously contained in Nanoscale/Bio-inspired and MetaMaterials in addition to Fundamentals of Nanoscale and Emergent Effects and Engineered Devices.

FY 2016 Accomplishments:

- Developed methods to stabilize extended solids at ambient temperatures and pressures.
- Demonstrated synthesis and stability to ambient temperature and pressure of high density extended carbon-based materials (clathrates, allotropes, nitrides, and oxides) at the multimilligram scale.
- Explored scalable production methods for fabrication of tough ceramic materials.
- Developed retrosynthetic pathways to fabricate extended solids at reduced pressures based on computational analysis and stabilization results.
- Further demonstrated the ability to assemble micron-scale, three dimensional (3D) and multiple material structures from nanoscale material constructs while preserving desirable nanoscale material properties.
- Continued to demonstrate pick and place assembly of centimeter-scale materials from micron-scale constructs while preserving desirable nanoscale material properties.
- Used non-natural polymer synthesis and screening systems to create affinity reagents against DARPA-defined targets.
- Developed strategy to adapt the non-natural polymer synthesis and screening system to modify affinity reagent properties.

FY 2017 Plans:

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate earlier developed methods to stabilize extended solids at ambient temperatures and pressures. - Demonstrate synthesis and stability of high density extended carbon-based materials (clathrates, allotropes, nitrides, and oxides) at the gram scale. - Demonstrate fabrication of tough ceramic materials at the >100-gram scale and complete validation testing. - Demonstrate synthetic pathways to fabricate extended solids at reduced pressures based on retrosynthetic designs and stabilization results. - Develop nanometer and micron-scale mechanical manipulation tools to support assembly tasks. - Build 1 centimeter or larger structures with controlled internal complexity from feedstock consisting of individual atoms or molecules. - Improve the binding affinity of non-natural polymers against DARPA-defined targets. - Generalize developed non-natural polymer library screening strategies across multiple target classes. ***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.			
Title: Basic Photon Science	32.305	30.050	30.200
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. Finally, 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. This thrust is an aggregation of programs previously contained in both Basic Photon Science and Nanoscale/Bio-inspired and MetaMaterials. ***FY 2016 Accomplishments:*** - Designed a rack-mounted package for mode-locked laser based optical frequency division microwave source. - Demonstrated Radio Frequency (RF) photonic bandpass filtering with micro-resonator optical frequency combs. - Demonstrated a remotely operating quartz microwave oscillator slaved via optical frequency comb based free-space (wireless) time and frequency transfer.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrated femtosecond time-resolved imaging at the nanometer scale with soft x-rays generated via high harmonic generation (tabletop scale x-ray source). - Demonstrated stability and characterization capabilities of extreme ultraviolet/soft x-ray attosecond end-station by measuring and characterizing isolated attosecond (10^-18 seconds) pulses. - Demonstrated proof-of-concept broadband chip-scale comb sources in multiple spectral regions. - Demonstrated proof-of-concept dual-comb quantum cascade lasers on the same chip in mid-infrared. - Demonstrated massively parallel spectroscopy in a lab setting for the detection of trace species in a cluttered environment using chip-scale frequency combs in multiple spectral regions. - Investigated the fundamental limits of photon transduction to enable a mechanistic description of the photodetector trade space including timing, resolution, efficiency and speed. - Initiated development of a theoretical framework based on the Plenoptic function to maximally exploit degrees of freedom of light for extracting information from complex scenes. - Initiated design of experiments to validate theoretical framework and models in complex scenes.			
FY 2017 Plans: - Develop a rack mounted package for mode-locked laser-based optical frequency division microwave source and all components for a chip-scale source. - Demonstrate chip-scale RF photonic down conversion and filtering based on optical frequency comb technology. - Show full integration of laser and end-station to realize a microjoule, isolated attosecond beamline, representing a new capability for research in ultrafast electronics. - Demonstrate tabletop sub-wavelength with nanometer spatial resolution (using tabletop high harmonic x-ray source). - Improve and tailor to specific DoD environments the performance of broadband chip-scale comb sources in multiple spectral regions. - Develop and characterize two-way time/frequency transfer protocols applicable to moving platforms. - Expand bandwidth, stability and robustness of chip-scale comb sources in multiple spectral regions to be compatible with spectroscopy of broadband absorbers such as chemical warfare agents. - Demonstrate proof-of-concept massively parallel spectroscopy in a lab setting for the detection of multiple trace species using chip-scale frequency combs in multiple spectral regions. - Determine a quantitative, first-principles description of photon detector performance for specific DoD platforms. - Improve the Plenoptic function theoretical framework and begin to validate with laboratory experiments to maximally exploit degrees of freedom of light and extract missing information from complex scenes. - Begin to theoretically determine the fundamental limits of maximum light/scene information extraction from a single viewpoint.			
FY 2018 Plans:			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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 massively parallel spectroscopy for the detection of multiple trace species in a cluttered environment using chip-scale frequency combs in multiple spectral regions. - Demonstrate cavity-enhanced comb-spectroscopy methods for massively parallel 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.			
Title: Fundamental Limits	-	8.093	16.586
Description: Understanding the fundamental limits (i.e., achievable boundaries) of scientific principles, processes and technologies is critical to better anticipate technological surprise for ourselves and our adversaries. 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 limitations of optical technologies, potential implications of basic biology on national security, and the ability for modeling and simulation to provide a better understanding of complex systems. This thrust is an aggregation of programs previously contained in both Nanoscale/Bio-inspired MetaMaterials and Fundamentals of Nanoscale and Emergent Effects and Engineered Devices. ***FY 2017 Plans:*** - Begin to develop modeling tools for development of system architectures that utilize engineered optical materials. - Develop device design principles to improve the efficiency and bandwidth of engineered optical materials. - Initiate experiments to understand how molecular-level modifications affect interactions with cell processes. - Develop information-theoretic models that efficiently generate representative climate statistics for improving predictability. - Explore the existence of prospective electromagnetic signaling channels within specific biosystems. - Begin to make quantitative predictions of transmit-receive characteristics of candidate bio-antennas in situ. - Begin to explore new approaches to store and process information with molecules. ***FY 2018 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate new design architectures and engineered optical materials on the sub-mm scale. - Develop plans to extend optical device design and fabrication from sub-mm scale to cm scale. - Evaluate information-theoretic and machine-learning models to measure improved predictions of representative statistics. - Demonstrate the technical capabilities - both theoretical and experimental - required to definitively determine if electromagnetic signaling is occurring in 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.			
Accomplishments/Planned Programs Subtotals	57.890	65.609	75.599

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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COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
TRS-01: *TRANSFORMATIVE SCIENCES*	-	31.547	53.070	59.877	-	59.877	68.337	73.342	67.249	67.941	-	-

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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Living Foundries	7.657	7.702	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 2016 Accomplishments:
- Demonstrated forward engineering of novel genetic systems using innovative computational design tools.
- Implemented evaluation tools for high-throughput testing, validation, and verification of engineered systems.
- Advanced novel learning systems that enable iterative design of engineered systems using integrated feedback of results to inform subsequent designs.
- Incorporated automated and scalable, large-scale DNA assembly, editing tools and processes into automated, integrated design-build-test-learn technologies for engineering novel biological systems.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Developed new chassis for engineering biology for improved metabolic flux for bioproduction. ***FY 2017 Plans:*** - Improve design tools through incorporation of large-scale process and test data for forward engineering novel genetic systems. - Integrate evaluation tools for high-throughput testing, validation, and verification of engineered systems. - Integrate novel learning systems that enable iterative design of engineered systems using integrated feedback of results to inform subsequent designs. - Optimize integration of design-build-test-learn technologies for high-fidelity, high-throughput, low cost engineering of biological systems. - Implement new biological chassis for improved yield and production of biochemicals. ***FY 2018 Plans:*** - Implement novel learning systems that enable iterative design of microbial systems using integrated feedback of results to inform subsequent designs. - 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.			
Title: Biological Robustness in Complex Settings (BRICS)	10.580	10.735	7.832
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 2016 Accomplishments:*** - Demonstrated methods to engineer organisms that are functionally stable over time in changing growth conditions. - Demonstrated methods to engineer complex communities of microorganisms with reliably controlled population dynamics. - Demonstrated methods to rationally engineer functional microbial communities of increasing complexity. ***FY 2017 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Combine consortia engineering technologies to develop communities that can be employed to solve specific DoD-relevant problems. - Demonstrate the functional stability of engineered communities in complex environments over relevant time scales. - Demonstrate potential for safe use of engineered consortia under conditions relevant to specific applications. ***FY 2018 Plans:*** - Continue development of design rules for functional engineered microbial communities. - Investigate parameters that contribute to the functional stability of engineered communities over relevant time scales in complex environments. - Define metrics that ensure the stability and safe use of engineered consortia outside of a controlled environment.			
Title: Understanding Biological Complexity	9.022	12.250	10.210
Description: Biological systems operate over an enormous range of spatial, physical, and temporal scales and span individual cells to multi-organism systems. This 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 enhance national security. Applications range from infectious disease mitigation or prevention, to predicting and leveraging biological systems for managing communities of microorganisms. 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. ***FY 2016 Accomplishments:*** - Initiated investigation into predictive design rules and engineering approaches for integrated biosystems. - Initiated research into biological systems with reduced complexity to facilitate predictive design for biological engineering. - Began researching cross-scale biological system responses to varying stimuli to understand defining characteristics of dynamic states. ***FY 2017 Plans:*** - Initiate efforts to assess the utility of new experimental model systems to inform practical engineering with complex biological systems. - Begin to identify candidate metrics and measurement technology relevant to engineering with complex biological systems. - Investigate synergistic integration of disease vector detection and control strategies. ***FY 2018 Plans:*** - Investigate engineering approaches for influencing the ability of complex biological systems to be controlled. - Investigate the utility of predictive design rules for engineering complex biological systems. - Assess the feasibility of building engineered controls into biological systems.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Test candidate engineering approaches relevant to control complex biological systems.			
Title: Social Simulation (SocialSim)* ***Description:*** * Previously Modeling and Forecasting of Social Dynamics (MFSD) The Social Simulation (SocialSim) program will develop 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 in their operations to great advantage. Existing approaches to understanding online information spread and evolution are largely based on specialized exercises that take considerable time to orchestrate and execute and have limited accuracy. A corresponding computational simulation has the potential to enable a deeper and more quantitative understanding of adversaries' messaging campaigns and their likely outcomes, as well as exploration of potential responses. ***FY 2016 Accomplishments:*** - Explored applicability of online game environments for understanding online social behavior. - Conducted workshop to explore the ethical and scientific issues surrounding understanding human social behavior online. ***FY 2017 Plans:*** - Explore alternative approaches for modeling and simulating the spread and evolution of information in online environments. - 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 2018 Plans:*** - Test the capability to simulate online phenomena such as cascades and gatekeeping. - Evaluate the performance of the social simulator in diverse scenarios in a single online environment. - Refine the underlying mechanisms to simulate the spread and evolution of information in online environments.	2.250	10.028	13.000
Title: Engineering Complex Systems ***Description:*** Engineering Complex Systems will pursue new approaches to engineer complex, multi-cellular systems for enhanced capabilities and function. Complex biological materials and 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.	-	10.355	15.825

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
FY 2017 Plans: - Investigate methods for specifying cellular behavior in response to environmental cues and positional information. - Begin development of biological systems that have genetically encoded three-dimensional forms of specified dimensions. - Begin development of gene expression circuits that confer desirable surface properties to a multi-cellular community. - Initiate development of gene expression circuits that confer autonomous pattern formation in a multi-cellular community. - Research methods to join living cells to non-living structural materials for the purpose of creating living building materials. ***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 to a multi-cellular community. - Continue development and testing of gene expression circuits that confer autonomous pattern formation in a multi-cellular community. - Demonstrate methods to join living cells to non-living structural materials for the purpose of creating living building materials.			
Title: New Functionalities for Biological Systems ***Description:*** Leveraging advances in synthetic biology and bioengineering, this program seeks to investigate novel approaches to identify and transfer biological functions into an organism or between organisms. Traditional research in this field has been limited to microbial systems and focused on imparting capabilities from one biological system to another. Instead, this work will investigate methods to biologically encode new functionalities in cell-free, multicellular, and/or multi-organism systems, using innovations from related areas of microbiology as well as micro- and nanotechnology. New capabilities within biological systems will enable advances in a variety of national security application areas. ***FY 2018 Plans:*** - Identify intrinsic or novel cell properties and structures that can be used as components of traditionally non-biological systems. - Investigate methods to guide assembly of biological sub-components. - Initiate investigation into novel approaches for transfer or control of biological functions to cell-free, multicellular, and/or multi-organism systems. - Develop new tools and techniques to rapidly screen organisms or biological systems for traits and mechanisms of interest.	-	-	9.510
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	2.038	2.000	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
to best practices. The applied research component of this program is funded in PE 0602715E, Project MBT-01 under Materials Processing and Manufacturing. ***FY 2016 Accomplishments:*** - Characterized material produced using micro-induction sintering process. - Developed fundamental process modeling tools for micro-induction sintering process. - Demonstrated approach to integrate the Open Manufacturing rapid qualification frameworks into a comprehensive computational tool. ***FY 2017 Plans:*** - Establish system for model curation, acquire models, and establish data formats for simulation and analysis of process, microstructure, and properties for additive manufacturing. - Assess and quantify the uncertainty in the Open Manufacturing framework model that accurately predicts part performance based on manufacturing method, environment and integrated probabilistic models.			
Accomplishments/Planned Programs Subtotals	31.547	53.070	59.877

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-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	52.736	57.791	43.126	-	43.126	47.882	46.456	46.456	46.456	-	-
MED-01: *BASIC OPERATIONAL MEDICAL SCIENCE*	-	52.736	57.791	43.126	-	43.126	47.882	46.456	46.456	46.456	-	-

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; 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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	56.544	57.791	65.685	-	65.685
Current President's Budget	52.736	57.791	43.126	-	43.126
Total Adjustments	-3.808	0.000	-22.559	-	-22.559
• 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	-2.007	0.000			
• SBIR/STTR Transfer	-1.801	0.000			
• TotalOtherAdjustments	-	-	-22.559	-	-22.559

Change Summary Explanation

FY 2016: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2017: N/A

FY 2018: Decrease reflects the completion of the Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT) program in FY 2017.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
Title: Analysis and Adaptation of Human Resilience	13.041	15.600	16.861
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 2016 Accomplishments:*** - Developed animal testbeds to evaluate human-relevant infection across multiple resilient species. - Assessed diagnostic technologies that can rapidly detect pathogen load and characterize the different stages of infection in multiple animal species. - Analyzed experimental results and bioinformatics datasets to discover key markers of tolerance. - Developed a bioinformatics library of acquired clinical retrospective data. ***FY 2017 Plans:*** - Explore methods for effectively screening animal susceptibility and disease tolerance to infection. - Collect, curate, and integrate retrospective datasets into the analysis of tolerance mechanisms. - Validate algorithms and analytical tools to facilitate the discovery of tolerance mechanisms. - Identify approaches for intervention based on novel tolerance mechanisms in animals. ***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.			
Title: Outpacing Infectious Disease	-	13.025	16.476
Description: 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. Today, protective measures such as antivirals			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
and vaccines are often circumvented by fast-mutating viruses that evolve to develop drug resistance. New approaches, such as enabling co-evolution and co-transmission of newly developed therapeutics to ultimately outcompete the pathogen, are needed in vaccine and antiviral design. 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. ***FY 2017 Plans:*** - Design and build pathogen-derived therapeutic interfering particles (TIPs) that control disease by interfering with the pathogen. - Develop dynamic in vitro platforms to test TIPs in vitro. - Assess the safety and efficacy of TIPs in vitro. - Initiate design of computational models to assess host-disease-therapeutic dynamics at the cellular and organismal levels. ***FY 2018 Plans:*** - Perform screening, optimization, and generalization of 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.			
Title: Predicting Disease Transmission from Animal Carriers ***Description:*** Many emerging infectious disease outbreaks have origins in animal reservoirs. This program will investigate how animal pathogens gain the ability to be transmitted to humans. Tools such as detailed molecular analysis of animal reservoirs and bioinformatics will be leveraged. Building on discoveries in this program, researchers will develop predictive models to forecast potential environments where conditions are most favorable for disease transmission between animals and humans. Predicting such areas is a key capability to mitigating unforeseen outbreaks originating in animal reservoirs. ***FY 2018 Plans:*** - Identify conditions with a high potential to facilitate transmission of animal pathogens to humans. - Initiate bioinformatics assessment of viruses known to have originated in animal reservoirs to identify key characteristics of pathogenicity. - Analyze host-pathogen interaction mechanisms to determine causal relationship with animal to human transmission.	-	-	9.789
Title: Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT)	33.400	23.066	-

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018

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.

FY 2016 Accomplishments:
- Established biodistribution maps in appropriate models resulting from varied delivery methods, formulations, and devices relevant to nucleic acid constructs for antibody production.
- Demonstrated protection conferred by delivery of nucleic acid constructs encoding two or more antibodies in validated infectious disease animal model.
- Submitted Investigational New Drug (IND) application for transient nucleic acid-based formats against infectious disease.
- Demonstrated increased protective response and duration of antibody-encoding nucleic acid constructs against infectious disease in a large animal model.
- Conducted IND-enabling non-clinical studies of DNA-monoclonal antibody (mAb) candidate.
- Delivered high-sensitivity assay methods for protein and nucleic acid biomarkers for incorporation into deployable devices.
- Delivered advanced materials for incorporation into disposable assay formats.
- Delivered advanced methods for reagent stabilization and delivery for incorporation into deployable devices.
- Delivered sample preparation methods for incorporation into deployable devices.
- Demonstrated optimized performance of developed bacterial/viral detection methods, assays, and materials using advanced no/low power microfluidic methods.

FY 2017 Plans:
- Demonstrate production of gene encoded antibodies in human safety trials.
- Demonstrate efficacy of gene encoded antibodies in a human clinical trial.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
- Demonstrate the ability to identify antibodies against infectious diseases from patients in less than thirty days. - Use current good manufacturing processes to synthesize formulations for animal challenge study.			
Title: Harnessing Biological Systems ***Description:*** The Harnessing Biological Systems program will explore 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 seeks to transition to a biocentric design approach, developing tools and understanding mechanisms to leverage evolutionary advances from the start. Key advances expected from this research include identifying approaches to discover and develop new classes of dynamic therapeutics for antibiotic-resistant bacteria. One example will be to identify 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. ***FY 2016 Accomplishments:*** - Initiated studies to enhance understanding of biological adaptability in response to external pressures. - Investigated predatory bacteria effectiveness against pathogens of interest. - Initiated studies of the relevant underlying mechanisms of bacterial predation. - Investigated dynamics of amoeba interactions with bacterial and fungal pathogens as a potential method for improved public health. ***FY 2017 Plans:*** - Investigate predatory bacteria effectiveness against pathogens of interest in in vivo models. - Investigate mechanisms of predation and potential resistance. - Develop quantitative models to describe predator-pathogen-host interactions. - Analyze biosynthetic pathways of the gut microbiota to discover and characterize disease tolerance-mediating metabolites.	6.295	6.100	-
Accomplishments/Planned Programs Subtotals	52.736	57.791	43.126

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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*

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	120.512	115.213	109.360	-	109.360	153.797	157.604	157.360	148.497	-	-
BT-01: *BIOMEDICAL TECHNOLOGY*	-	120.512	115.213	109.360	-	109.360	153.797	157.604	157.360	148.497	-	-

A. Mission Description and Budget Item Justification

This Program Element focuses on applied research for medical related technology, information, processes, materials, systems, and devices. Successful battlefield medical technologies and neural interface technologies developed within this Program Element address a broad range of DoD challenges. Example battlefield medical technologies include continued understanding of infection biomarkers to lead to the development of detection devices that can be self-administered and provide a faster ability to diagnose and prevent widespread infection in-theater. Complementary battlefield technologies will be implemented in a predictive platform for forecasting disease outbreak or rapidly developing a medical countermeasure to outpace a disease outbreak, as well as the capability to manufacture field-relevant pharmaceuticals in theater. New neural architectures and data processing algorithms will be developed to interface the nervous system with multiple devices, enabling control of robotic prosthetic-limb technology. 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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	114.262	115.213	109.817	-	109.817
Current President's Budget	120.512	115.213	109.360	-	109.360
Total Adjustments	6.250	0.000	-0.457	-	-0.457
• 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	9.889	0.000			
• SBIR/STTR Transfer	-3.639	0.000			
• TotalOtherAdjustments	-	-	-0.457	-	-0.457

Change Summary Explanation

FY 2016: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2017: N/A
FY 2018: Decrease reflects minor program repricing.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
Title: Restoration of Brain Function Following Trauma	18.800	19.400	17.386

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 therapeutics approaches that can bypass and/or recover the neural functions underlying memory, which are often disrupted as a consequence of TBI.

FY 2016 Accomplishments:
- Refined computational model of memory toward distinguishing underlying neural activity related to remembered vs. forgotten memories in three categories and spatial and non-spatial associations.
- Investigated and tested optimal stimulation parameters for improving performance on spatial memory tasks.
- Utilized defined biomarkers of memory encoding and retrieval to adaptively modulate patterned electrical stimulation to dynamically drive neural networks into states optimized for memory encoding and retrieval processes.
- Determined the neural signatures underlying stimulation-induced memory restoration.
- Designed, developed and validated both external and implantable hardware and software systems for an integrated memory restoration system.

FY 2017 Plans:
- Demonstrate improvement of human performance on spatial and semantic memory tasks through the use of real-time, closed-loop, biomarker-driven stimulation.
- Utilize clinical data and computational model developments to refine hardware and software components.
- Fabricate and test integrated device for memory restoration in clinical patients.
- Develop computational model of integrated neural, physiological, and environmental effects on neural replay and subsequent memory recall in the context of task performance relevant to military training and/or operations.
- Develop and use a real-time intervention and an interface system to assess, enable, and improve skill performance in human participants.

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.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
- 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. - Demonstrate use of a closed-loop, non-invasive intervention to facilitate neural replay and subsequent performance of skills.			
Title: Neuro-Adaptive Technology	31.478	26.388	20.060
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 2016 Accomplishments:*** - Developed and applied data co-registration and fusion methods for neural activity, wiring, and behavior. - Generated and annotated first intact neural tissue volumes to elucidate microstructure and connections in three dimensions. - Designed algorithms for automatic cell identification and optical-signal estimation. - Elucidated neural circuit dynamics using structurally-informed network models. - Refined optical techniques for imaging large volumes of neural tissue. - Expanded data curation architecture, databases, and analytical tools to distribute generated data to the neuroscience community. - Developed methods for automatically detecting and removing noise or contamination from datasets. - Delivered a hierarchical computational model of key brain networks that captures features relevant for psychiatric illness and its treatment. - Developed and refined neural state acquisition, classification, and control algorithms to support closed-loop control in an implantable neural device. - Initiated characterization of neural network plasticity during behavioral training. ***FY 2017 Plans:***			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
- Complete high-resolution large-brain imaging using novel optical tools. - Demonstrate optimized optical protocols for human tissue. - Integrate neural state classification, stimulation parameters, and targeted brain networks into a comprehensive computational model to support disorder-specific closed-loop implantable neural devices. - Demonstrate real-time application of integrated disorder-specific stimulation parameters and targeted brain networks. - Utilize clinical data and computational model determinants to refine hardware and software components of an implantable neural device. - Begin fabrication of updated devices for multi-site brain stimulation. - Initiate submission process for regulatory approval of updated parameters of the novel neural device. ***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 in clinical patients to demonstrate modulation of disorder-specific psychiatric or neurologic behaviors through real-time, closed-loop stimulation.			
Title: Prosthetic Hand Proprioception & Touch Interfaces (HAPTIX)	18.900	18.500	15.700
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 2016 Accomplishments:*** - Integrated interface and electronic systems technology for use in human amputees to control and receive intuitive sensory feedback from a prosthetic device. - Demonstrated closed-loop control of a virtual prosthesis. - Performed safety and efficacy testing of HAPTIX system components to capture motor control signals and provided electrical sensory stimulation through the peripheral nervous system. - Demonstrated in vivo functionality of next-generation HAPTIX peripheral interface technology. - Finalized HAPTIX system prosthetic limb technology, completed sensorization, and began manufacturing of devices.			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
- Implemented draft version of outcome metrics for quantifying effects of HAPTIX technology and began validation studies. ***FY 2017 Plans:*** - Initiate functional validation of input/output signal transfer and wireless communication of power and data. - Initiate safety studies of HAPTIX system to support submission of investigational device exemption (IDE) application to the U.S. Food and Drug Administration (FDA). - Demonstrate novel nerve stimulation and recording technologies. - Demonstrate closed-loop control of a physical prosthesis. ***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.			
Title: Performance Optimization in Complex Environments	11.650	18.475	21.530
Description: The Performance Optimization in Complex Environments program focuses on leveraging advances in and integration of sensors, computation, and analytics to enable optimum human performance in complex environments. Device technology has advanced to the point where human beings can be instrumented with and connected to a broad range of unobtrusive, always-on physiological, cognitive, and contextual sensors and information systems. At the same time, body-area networks, wearable displays, haptics, and other novel forms of human-computer interfaces have advanced enough that convenient real-time multifactor analysis for neurofeedback and biofeedback are within reach. The Performance Optimization in Complex Environments program will first focus on developing prototyping and manufacturing techniques necessary to integrate these two advancing areas to enable optimal performance in a wide variety of activities from learning and training to specialized tasking, and to mitigate the effects of physical injury, age, and mental impairment. Research will also focus on understanding various forms of sensing and actuation to improve outcomes and how biofeedback over time can alter human capability. Technologies developed through this program will provide a foundation of novel value propositions to the warfighter in terms of restoration of lost capability, situational awareness, resilience, cognitive and physical effectiveness, and force multiplication. ***FY 2016 Accomplishments:*** - Initiated research on biological interfaces for enabling input-output of information. - Explored and identified scalable technologies for reading and writing biological signals. - Investigated the neural pathways and mechanisms underlying naturalistic perception. ***FY 2017 Plans:*** - Refine component technologies to increase scale of information input-output.			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
- Identify component technologies to be integrated into a device for reading and writing biological signals. - Investigate novel approaches to reduce the size, weight, and power requirements for the integrated device. - Develop preliminary system architectures for highly-scaled input-output of information. - Develop biological interfaces with the precision to target individual neurons. ***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. - 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.			
Title: Enhanced Monitoring of Health and Disease	-	12.100	11.280
Description: The overarching goal of the Enhanced Monitoring of Health and Disease program is to leverage 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. Research in this thrust 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 thrust 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 2017 Plans:*** - Collect biological samples to assess asymptomatic, symptomatic, and co-infection rates among a research cohort. - Evaluate banked and new samples from clinical cohort or intervention trials to discover candidate prognostic biomarkers for the prediction of contagiousness. - Identify key parameters of robust epidemiological models for predicting disease transmission. - Evaluate the predictive capability of dynamic, ensemble-based epidemiological models for disease forecasting. ***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.			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
- Evaluate models and prognostic tests for accuracy prospectively.			
Title: Generalizing Complex Biological Signals ***Description:*** Recent advances in neurotechnology have created the ability to interface with the nervous system at high resolution and precision. To date, sending and receiving data via these interfaces has required researchers to develop new signal processing algorithms for each user. This program seeks to generalize complex biological signals across users via new architectures and systems, thus producing a flexible neural interface protocol among users that can receive and react to environmental, physiological, and neural information. Future neurotechnology devices based on this generalized communication protocol may enable human-machine and human-human interaction for communication or distributing tasking to balance workload. ***FY 2018 Plans:*** - Initialize research to identify multimodal input processing and real-time feedback. - Begin analysis for common signal processing architecture in existing biological signal data. - Conduct preliminary closed-loop studies to understand human-machine and human-human interaction.	-	-	9.490
Title: Pandemic Prevention ***Description:*** Effective pandemic response relies on the ability to anticipate where outbreaks will occur as well as rapidly accelerating medical 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 within this program will investigate new methods improving the manufacturability, distribution, and delivery of novel therapeutics. Technologies developed within this program 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.	-	-	13.914
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	22.461	13.441	-

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 2016 Accomplishments:*** - Optimized formulation of transient nucleic acid formats for storage stability at room temperature for at least six months. - Demonstrated continuous production of nucleic acid formats for transient immunity to viral, bacterial, and/or antibiotic-resistant bacterial pathogens for population-scale use. - Incorporated device optimizations identified as a result of first-generation, integrated diagnostic device testing. - Produced integrated diagnostic device prototypes designed for relevance to physician office, remote clinic, and low-resourced settings. - Measured quantitative performance of integrated diagnostic device prototypes. ***FY 2017 Plans:*** - Initiate regulatory approval submission package for transient nucleic-acid based formats against infectious disease with safety and efficacy data. - Demonstrate production of gene encoded antibodies in human safety trials. - Conduct a dose escalation study of nucleic acid-encoded antibody against antibiotic resistant bacteria.			
Title: Tactical Biomedical Technologies	7.150	6.909	-
Description: The Tactical Biomedical Technologies thrust will develop 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 is 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 is also investigating 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 will also develop 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. ***FY 2016 Accomplishments:***			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
- Developed continuous synthesis of Ciprofloxacin (from basic starting materials) in miniaturized integrated manufacturing platform. - Demonstrated end-to-end manufacturing and solid formulation of Ciprofloxacin in miniaturized integrated manufacturing platform. - Designed and developed cell-based and cell-free protein expression of four additional biologics including Insulin, Factor VIIa, Interferon, Hepatitis B Surface Antigen, Tissue Plasminogen Activator, Granulocyte Colony-Stimulating Factor, and Rituxmab. - Optimized miniaturized biologics manufacturing platform components, including bioreactor, purification, and analytical modules, and begin systems integration of components for both cell-based and cell-free protein expression platforms. ***FY 2017 Plans:*** - Develop continuous synthesis of Lisinopril and Linezolid in miniaturized integrated manufacturing platform. - Demonstrate end-to-end manufacturing and solid formulation of Lisinopril and Linezolid in miniaturized integrated manufacturing platform. - Demonstrate end-to-end manufacturing of four additional biologics in miniaturized integrated platform. - Develop a miniaturized integrated manufacturing platform produce Ciprofloxacin under Good Manufacturing Practices.			
Title: Dialysis-Like Therapeutics (DLT) ***Description:*** Sepsis, a bacterial infection of the blood stream, is a significant cause of injury and death among combat-injured soldiers. The goal of this program was to develop a portable device capable of controlling relevant components in the blood volume on clinically relevant time scales. Significant advances were made in sensing in complex biologic fluids, complex fluid manipulation, separation of components from these fluids, and mathematical descriptions capable of providing predictive control over the closed loop process. The developed device could save the lives of thousands of military patients each year by effectively treating sepsis and associated complications. Additionally, the device may be effective as a medical countermeasure against various chemical and biological (chem-bio) threat agents, such as viruses, bacteria, fungi, and toxins. Applied research under this program applied existing component technologies and integrated these products to create a complete blood purification system for use in the treatment of sepsis. Included in this effort was development, integration and demonstration of non-fouling, continuous sensors for complex biological fluids; implementation of high-flow microfluidic structures that do not require the use of anticoagulation; application of intrinsic separation technologies that do not require pathogen specific molecular labels or binding chemistries; and refinement of predictive modeling and control (mathematical formalism) with sufficient fidelity to enable agile adaptive closed-loop therapy. ***FY 2016 Accomplishments:*** - Completed fabrication of the first generation of integrated DLT device prototypes. - Completed safety studies of the integrated DLT device in a large-animal model.	5.073	-	-

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Initiated safety studies focused on pathogen removal in large-animal model.			
Title: Warrior Web	5.000	-	-
Description: Musculoskeletal injury and fatigue to the warfighter caused by dynamic events on the battlefield not only impact immediate mission readiness, but also can have a deleterious effect on the warfighter throughout his/her life. The Warrior Web program mitigated that impact by developing an adaptive, quasi-active, joint support sub-system that can be integrated into current soldier systems. Because this sub-system is compliant and transparent to the user, it can reduce the injuries sustained by warfighters while allowing them to maintain performance. Success in this program required the integration of component technologies in areas such as regenerative kinetic energy harvesting to offset power/energy demands; human performance, system, and component modeling; novel materials and dynamic stiffness; actuation; controls and human interface; and power distribution/energy storage. The final system weighed no more than 9kg and required no more than 100W of external power. Allowing the warfighter to perform missions with reduced risk of injuries can have immediate effects on mission readiness, soldier survivability, mission performance, and the long-term health of our veterans. ***FY 2016 Accomplishments:*** - Revised full suit design and implementation based on laboratory evaluations. - Continued to evaluate prototype Warrior Web systems via soldier tests in laboratory and field environments. - Continued to pursue research and development of technologies to augment human performance and support rehabilitation.			
Accomplishments/Planned Programs Subtotals	120.512	115.213	109.360

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	331.720	353.635	392.784	-	392.784	380.359	389.940	384.550	380.931	-	-
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	34.233	42.459	49.919	-	49.919	59.775	52.113	70.413	70.413	-	-
IT-03: *INFORMATION ASSURANCE AND SURVIVABILITY*	-	209.557	255.137	260.757	-	260.757	235.669	248.985	234.201	222.597	-	-
IT-04: *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*	-	46.508	56.039	82.108	-	82.108	84.915	88.842	79.936	87.921	-	-
IT-05: *CYBER TECHNOLOGY*	-	41.422	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

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 even under 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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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*

The Cyber Technology project developed technology to increase the security of military information systems and the effectiveness of cyber operations. Over the past decade the DoD has embraced net-centric warfare by integrating people, platforms, weapons, sensors, and decision aids. Adversaries seek to limit this force multiplier through cyber attacks intended to degrade, disrupt, or deny military computing, communications, and networking systems. Technologies developed under the Cyber Technology project ensured DoD net-centric capabilities survive adversary cyber attacks and enabled new cyber-warfighting capabilities.

B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	341.358	353.635	353.925	-	353.925
Current President's Budget	331.720	353.635	392.784	-	392.784
Total Adjustments	-9.638	0.000	38.859	-	38.859
• 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	1.232	0.000			
• SBIR/STTR Transfer	-10.870	0.000			
• TotalOtherAdjustments	-	-	38.859	-	38.859

Change Summary Explanation

FY 2016: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.

FY 2017: N/A

FY 2018: Increase reflects new start programs addressing machine learning technologies in the High Productivity, High Performance Responsive Architectures and Language Understanding and Symbiotic Automation projects.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	34.233	42.459	49.919	-	49.919	59.775	52.113	70.413	70.413	-	-

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 2016	FY 2017	FY 2018
Title: Hierarchical Identify Verify Exploit (HIVE)*	4.000	16.709	19.919
Description: *Formerly Portable AnaLyticS (PALS) 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 2016 Accomplishments:*** - Identified common graph primitives that would accelerate the execution of DoD-specific applications.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Explored the applications benefitting from the unique architecture and whether unique hardware design allows for processors for unique military applications. ***FY 2017 Plans:*** - Identify domain specific primitives that would accelerate performance by moving data-intensive functionality to appropriate processing system data storage levels and specifically a memory 3D stack logic layer. - Prove, via simulation, improvement in the performance of core graph primitives including matrix indexing and assignment, matrix element-wise addition and multiplication, matrix - matrix products, and matrix scaling and reduction by 100X. - Develop graph application toolsets which take advantage of the new chip architectures. ***FY 2018 Plans:*** - Demonstrate the toolsets that can be applied to four different classes of DoD problems to include counter terrorism, cyber security, tactical decision making, and intelligence exploitation. - Demonstrate that these problems can run on prototype hardware systems and measure both power and performance improvements of the new hardware. - Use this information to create a chip design for future fabrication.			
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 2016 Accomplishments:*** - Improved the operation of a laser-based scanning tool to allow for its use in validating a wider array of microelectronic parts. - Demonstrated performance improvements on the order of 10x in the scanning tool, allowing for better accuracy in detecting counterfeit parts. ***FY 2017 Plans:*** - Study the effect of high stress on the reliability of conventionally fabricated commercial off the shelf (COTS) and Government off the shelf (GOTS) electronic components.	4.847	5.000	4.000

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Continue prototype system enhancements to the laser scanning tools. ***FY 2018 Plans:*** - Continue to study high stress effects on conventionally-fabricated COTS and GOTS electronic components.			
Title: Spectrum Collaboration Challenge (SC2)*	5.000	14.750	18.000
Description: * Formerly Spectrum Grand Challenge 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 others' 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 2016 Accomplishments:*** - Defined SC2 rules governing eligibility as well how the competition will be conducted and scored and prizes ultimately awarded. - Identified a host and began development of the world's largest wireless environment emulator and research environment for the competition. - Announced the Spectrum Collaboration Challenge and stood up website to collect contact information. ***FY 2017 Plans:*** - Hold qualifying event for open participation in the first phase of the competition. - Select performers based on proposals for the competition's Proposal Track. - Complete design, build out and test of large-scale spectrum testbed. - Conduct competition scrimmages to allow competitor's to prepare for the Preliminary Event. ***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: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Develop visualizations and scoring for large-scale public event.			
Title: RF Machine Learning Systems (RFMLS) ***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 for 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. - Define a composable system architecture that enables multiple research teams to each confront a separate sub-system of the RF processing chain. - Quantify sub-system technology development requirements that support system performance goals by analyzing a variety of scenarios that are currently hand specified today. - Begin development of machine learning algorithms applied to the individual sub-system technologies.	-	-	8.000
Title: Cortical Processor* ***Description:*** *Formerly Complexity Management Hardware The Cortical Processor program aims to develop 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 could yield 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 will develop hardware implementations that gracefully handle multiple data streams and limit the programming burden required for sensing and interpreting a complex scenario. The program will further be enabled by bio-inspired algorithms that benefit from research into biological learning and data processing. Cortical Processor's applied research component will investigate silicon circuit designs that are most suitable for high-performance, low-power, real-time sensing and data processing.	6.000	6.000	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
FY 2016 Accomplishments: - Benchmarked the accuracy of new bio-inspired machine learning features by performing a variety of recognition and control tasks. - Demonstrated the ability to manage multiple data streams with interlaced information. - Created high level hardware concepts for efficient machine learning using bio-inspired approaches. ***FY 2017 Plans:*** - Compare various bio-inspired algorithms' ability to extract complex information from feature-rich data sets. - Quantify the benefits of various architecture approaches to the management of large data streams when overlaid with contextual information. - Translate new algorithms to high level circuit implementations to show the power and processing requirements. - Fabricate bio-inspired machine learning chips capable of training and recognizing patterns in multiple, rich data streams.			
Title: Power Efficiency Revolution For Embedded Computing Technologies (PERFECT)	14.386	-	-
Description: The Power Efficiency Revolution For Embedded Computing Technologies (PERFECT) program developed low-power, specialized, resilient data processing technologies to meet the requirements of next-generation Intelligence, Surveillance, and Reconnaissance (ISR) systems. Current embedded ISR applications rely on commercial processors designed for large data centers and therefore struggle to perform within the power and space limitations of platforms such as unmanned vehicles. As a result, these platforms often need to wirelessly access remote processing resources, potentially denying warfighters access to critical real-time information. Access to remote processing resources can also become unavailable in contested environments. To resolve this issue, PERFECT developed design tools and techniques to enable ISR sensor systems to process information locally, onboard the platform. These techniques should allow for processing data at lower voltages, speeding up data processing with specialized accelerators, and ensuring system reliability. ***FY 2016 Accomplishments:*** - Selected the implementation and transition target applications of vision, graph processing, and machine learning. Focused PERFECT teams' technologies to most effectively support future target application demonstrations. - Integrated modeling and evaluation environment, combining separate optimization tools for power, resiliency, and performance. - Demonstrated High Level Source-to-Source transformation targeting PERFECT program specialization simulators. Optimized/ vectorized code was generated that exploits explicit memory movement and dynamic voltage and frequency control for performance efficiency. - Demonstrated a near memory Fast Fourier transform accelerator supporting synthetic aperture radar and space-time adaptive processing using PERFECT architecture.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrated the benefits of specialization, using the PERFECT Vision Chip design as an example, by emulating the execution of major vision kernels to attain peak efficiencies.			
Accomplishments/Planned Programs Subtotals	34.233	42.459	49.919

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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COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
IT-03: *INFORMATION ASSURANCE AND SURVIVABILITY*	-	209.557	255.137	260.757	-	260.757	235.669	248.985	234.201	222.597	-	-

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 2016	FY 2017	FY 2018
Title: Rapid Attack Detection, Isolation and Characterization Systems (RADICS)	17.513	26.500	32.900

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 2016 Accomplishments:
- Explored design options for systems to detect anomalies in the physics of grid operation that may be indicative of the initial stages of a cyber attack.
- Studied options to enable network isolation of utilities under cyber attack, including the ad hoc formation of a secure emergency network using available communications links.
- Created initial designs of software tools to enable rapid localization and characterization of cyber attacks on the IT and Industrial Control Systems (ICS) networks of utilities.
- Conceptualized simulation-backed exercises to demonstrate the capabilities of tools and systems to potential transition partners.

FY 2017 Plans:
- Develop initial prototypes to detect anomalies in the physics of grid operation that may be indicative of the initial stages of a cyber attack.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Develop initial prototype tools to enable network isolation of utilities under cyber attack, including the ad hoc formation of a secure emergency network using available communications links. - Develop initial prototypes to enable rapid localization and characterization of cyber attacks on the IT and ICS networks of utilities. - Conduct the first simulation-backed exercise to assess the capabilities of tools and explore relevant concepts of operation for supporting the recovery of power in the aftermath of a large-scale outage due to cyber-enabled attack on the power grid. - Explore and design techniques to predict the nature and extent of cascading faults across large sections of a power grid. ***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 ICS devices and networks to encompass a wider range of equipment and network protocols used in U.S. electrical infrastructure. - Conduct simulation-backed exercises to assess the capabilities of prototypes, explore relevant concepts of operation for supporting the recovery of power, and demonstrate the systems to potential transition partners. - Develop prototype capability to maintain and expand situational awareness in the aftermath of a cyber-enabled attack. - Explore and design techniques to monitor ICS networks for signs of cyber compromise during restart operations.			
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 not only high-volume flooding attacks of hundreds of gigabits per second, but more subtle low-volume attacks that evade traditional intrusion detection systems while causing exhaustion of server processor and memory capacity. 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 2016 Accomplishments:*** - Explored alternative architectures and algorithms that enable physical and/or logical dispersion of likely DDoS targets (e.g., servers and cloud computing facilities) to complicate the location and targeting of these cyber resources by DDoS attackers. - Proposed network maneuver and deception techniques that increase adversary work factors in target development, attack planning, and execution.	14.996	24.800	29.150

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Conceptualized the means for enabling servers and similar DDoS targets to sense the presence of DDoS attacks (especially low-volume attacks) and to adapt their operation in real time to mitigate attacks while preserving performance for legitimate users. ***FY 2017 Plans:*** - Develop network dispersion, maneuver, and adaptive response techniques that increase adversary work factors. - Develop testing capabilities to support iterative experimentation and demonstration of techniques. - Perform system-level demonstrations and subject systems to critical assessments to pinpoint design weaknesses and vulnerabilities. - Assess performance of developed systems with respect to program metrics including response time following attack, percentage recovery of application utility following attack, and application degradation in the absence of attack. ***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. - Perform final testing of dispersion, maneuver, and adaptive response with respect to program metrics. - Conduct military field exercises in collaboration with transition partners to elicit feedback on XD3 features, capabilities, and concepts of operation. - Incorporate feedback received during field exercises and re-test systems against program metrics to verify intended operation and desired transitionable features.			
Title: Leveraging the Analog Domain for Security (LADS)	17.000	20.500	23.000
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 2016 Accomplishments:*** - Formulated approaches for measuring side channel signals such as radio frequency and acoustic emissions, power consumption, heat generation, differential fault analysis, and timing-based effects in noisy environments. - Investigated rule-based and statistical classification techniques for discriminating side channel signals emitted from computing components, devices, and systems operating in compromised/faulty states from those operating in secure/correct states.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Proposed approaches for predicting side channel emissions given knowledge of the computing system hardware and executed code. ***FY 2017 Plans:*** - Develop quantitative models for side channel signals emitted from systems operating in secure/correct states and from systems operating in compromised/faulty states and validate the models through laboratory measurements. - Assess the practicality of initial techniques for discriminating side channel signals emitted from systems operating in compromised/faulty states from those operating in secure/correct states by computing receiver operating characteristics (probability of detection versus probability of false alarm). - Develop statistical models for side channel emissions given imprecise/probabilistic knowledge of the executed code. ***FY 2018 Plans:*** - Implement an evaluation framework for Internet of Things (IoT) devices including instrumentation of the platforms, representative test software, program analysis and introspection. - Map selected features from the analog side channels to supervised 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 the different IoT devices using the evaluation framework and explore performance tradeoffs including accuracy and sensor distance.			
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 break 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 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 2016 Accomplishments:*** - Implemented secure multiparty computation, secure database queries, differential privacy and remote attestation techniques in initial prototypes suitable for integration on commodity cloud infrastructures. - Developed a prototype evaluation platform and metrics/analysis tools on which privacy technologies can be tested and metrics computed.	17.600	19.000	22.300

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Initiated quantification of benefits of privacy technologies in the context of individual and enterprise use cases. ***FY 2017 Plans:*** - Optimize privacy prototypes that implement secure multiparty computation, secure database queries, differential privacy and remote attestation techniques, and test these prototypes on enterprise networks. - Quantify privacy benefits and the costs in terms of computational overhead and latency. - Perform detailed studies of the security implications of the techniques in terms of confidentiality, integrity, and availability of private information. - Identify potential commercial and military transition partners for use of privacy technologies based on identified high priority use cases. ***FY 2018 Plans:*** - Develop and demonstrate a privacy-preserving information system using secure multiparty computation, secure database queries, differential privacy, and remote attestation techniques, in which individual and aggregate privacy desires can be easily understood and implemented consistently. - Demonstrate techniques for confirming that privacy preferences of data owners have been successfully received and honored. - Demonstrate privacy protection in human data communication and collaboration on enterprise networks.			
Title: Cyber Fault-tolerant Attack Recovery (CFAR)	20.149	22.500	20.030
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 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 2016 Accomplishments:*** - Demonstrated replicated systems that exhibit sufficient variability to produce differences in behavior under attack. - Implemented and tested techniques for quickly detecting behavioral differences across replicated systems. - Evaluated multiple potential architectures for achieving cyber fault-tolerance for mission-critical systems running on commercial computing technologies. - Worked with potential transition partners to evaluate military computing systems as candidates for technology refresh with CFAR technologies. ***FY 2017 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Create replication variants from binary code to extend CFAR defenses to systems for which source code is not available. - Develop methods to produce proofs of semantic equivalence across variants, which will contribute to assurance cases that systems protected with CFAR technology behave identically to the original systems. - Develop robust cyber fault-tolerant models that handle the highly correlated and frequent faults that may result from a cyber-attack. - Experiment with an early CFAR prototype on a representative mission system. ***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. - Develop technical documentation of design choices, data supporting the performance claims of components and the integrated CFAR system(s), and experimental results.			
Title: Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT)	22.000	24.938	13.520
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 will be developed in coordination with operational commands. ***FY 2016 Accomplishments:*** - Developed fight-through strategies that rapidly restore networked communication in the face of a wide variety of common network failure modes as well as cyber attacks against network infrastructure. - Demonstrated performance at the component and subsystem levels, to include real-time network analytics, holistic decision systems, and dynamically configurable protocol stacks. - Assessed EdgeCT component and system designs for potential weaknesses, vulnerabilities, and countermeasures associated with cyber attacks against network infrastructure, or against EdgeCT systems themselves.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Initiated development of software prototypes suitable for laboratory experimentation with operational commands. ***FY 2017 Plans:*** - Demonstrate and evaluate system prototypes against program metrics to verify adequate performance for cumulative network utility, recovery time, and network overhead. - Explore modes of user interaction and system concepts of operation with one or more operational commands, and bring software prototypes to an initial field experiment in collaboration with an operational command. - Extend usage and testing scenarios to include multiple forms of simultaneous failures and cyber attacks within the wide area network. - Expose developed systems to red team analysis to identify potential operational vulnerabilities and focus further hardening of the technologies. ***FY 2018 Plans:*** - Foster transition activities through participation in a live military field exercise that will demonstrate EdgeCT capabilities in overcoming impairments to command and control (C2) and related networked applications. - Address and rectify operational vulnerabilities identified by red teams through additional design and testing activities within program testbeds. - Pursue transition to commercial network operators and to Defense Information Systems Agency through demonstrations and testing within service provider facilities, subjecting EdgeCT to impairments observed in network environments.			
Title: Dispersed Computing (DC) ***Description:*** The Dispersed Computing (DC) program will address research challenges encountered in the Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT) program by 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 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 DC program will develop a dispersed computing architecture that results in more efficient utilization of storage, processing, and networking resources. A key enabler for DC is the recent introduction by vendors of network elements that can be dual-purposed as computational elements. Under DC, these dual-purposed network-compute elements will be used to eliminate bottlenecks/chokepoints and mitigate impossible backhaul requirements by opportunistically moving code to data (and vice versa) given network conditions and available network-compute elements. With DC technology, the network becomes the cloud (and vice versa), and computation is performed where it is most efficient to do so.	-	13.000	17.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
FY 2017 Plans: - Devise data replication/decentralization strategies that enable local processing of data to greatly reduce loads on the network. - Explore the potential for adapting modern distributed computing paradigms such as MapReduce to run on dispersed DC-enabled network-compute elements and virtual computing clusters. - Design protocols that enable the DC architecture to run reliably and efficiently on tactical networks that exhibit disruptions, intermittent connectivity, and low bandwidth. ***FY 2018 Plans:*** - Complete initial prototypes of programmable protocol stacks operating on network-compute elements to boost network transport of code and data and to demonstrate the tailoring of protocols to the needs of specific military applications such as command and control (C2) 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, combatant commands, or other DoD stakeholders.			
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 2016 Accomplishments:*** - Refined designs based on measured results from test site hardware. - Developed transaction model for reader-to-dielet interrogation. - Selected best-fit Phase 1 technologies for inclusion on Phase 2 dielet designs, based on validated hardware measurements and objective analysis of design compatibility. - Refined dielet singulation, test and insertion methodology and fragility design based on mechanical testing of surrogate dielets. ***FY 2017 Plans:***	21.000	18.000	6.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Design and manufacture prototype SHIELD dielets, integrating best-fit technologies selected during Phase 1. - Develop hardware demonstration vehicle to evaluate Phase 1 power and sensor technologies in 65 nanometer complementary metal-oxide-semiconductor (CMOS). - Initiate functional and performance testing of manufactured SHIELD dielets. - Refine methods for dielet insertion into integrated circuit (IC) packages. - Build and test network appliance and server network for testing. ***FY 2018 Plans:*** - Demonstrate the SHIELD concept of operation in an actual or environmental facsimile of an integrated circuit supply chain. - Incorporate SHIELD dielets into 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.			
Title: Enhanced Attribution ***Description:*** The Enhanced Attribution program, building upon the Active Cyber Defense program, will develop technologies to associate the malicious actions of cyber adversaries to individual cyber operators and then to enable the government to reveal publicly the malicious actions of individual cyber operators without damaging sources and methods. Technologies of interest include new approaches for identification of malicious cyber operators, techniques to deconstruct their software tools and actions into semantically rich and compressed knowledge representations, algorithms for developing predictive behavioral characteristics, and methods for confirming this information with other commercial and public sources of data. As Enhanced Attribution technologies mature and show promise they will be implemented in tools for evaluation by potential transition sponsors. ***FY 2016 Accomplishments:*** - Formulated approaches for associating malicious actions with individual cyber operators. - Developed a concept for public attribution without revealing sources and methods. - Identified initial open source and commercially available data sources that can be used to confirm a cyber operations model. ***FY 2017 Plans:*** - Develop an ontology of cyber operator actions and identify useful metadata. - Develop and apply flexible database technology to support storage and causal relationship identification of operational cyber data. - Develop initial attribution modules to summarize behavioral characteristics for at least two computing platforms. - Conduct an initial adversarial evaluation against a simulated threat to provide feedback and drive future development goals.	8.000	17.500	23.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Develop automated techniques to detect phishing attacks and to defeat adversary social engineering activities before they can extract sensitive information from vulnerable individuals. ***FY 2018 Plans:*** - Reduce computational and bandwidth requirements for attribution modules. - Connect the basic attribution technologies and demonstrate the capability to generate narrative descriptions of cyber operator activities. - Demonstrate anticipatory analytics for adversary cyber operator actions. - Conduct an adversarial evaluation against a simulated threat in collaboration with transition partner operators.			
Title: System Security Integrated Through Hardware and software (SSITH) ***Description:*** The System Security Integrated Through Hardware and Software (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 2017 Plans:*** - Define new hardware architectures that implement scalable, flexible, and robust protection against external attacks on hardware. - 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 Plans:*** - Implement new hardware architectures 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.	-	12.000	19.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Evaluate SSITH security approaches through independent Red Team attack on the security architectures as implemented in hardware. - Define and start full system hardware demonstrations of security architectures.			
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. Initial funding for this effort was provided in Project IT-05. Funding continues in Project IT-03 for testing, evaluation and optimization through participation in tactical level exercises and for integrating Plan X technologies into transition partner systems. ***FY 2017 Plans:*** - Refine Plan X capabilities to provide operators with enhanced cyber situational awareness and to enable operators to execute cyber warfare missions with projections of cyber collateral damage. - Demonstrate capabilities in multiple military cyber exercises such as Army Warfighting Assessment (AWA), Cyber Guard, Cyber Flag, and Red Flag. - Refine operator workflows and operational use cases based on feedback gathered during exercises and user studies. ***FY 2018 Plans:*** - Work with transition partners, such as U.S. Cyber Command (USCYBERCOM), U.S. Army Cyber Command (ARCYBER), and U.S. Army Program Executive Office Enterprise Information Systems (PEO EIS) to integrate Plan X into transition partner systems.	-	23.349	7.546
Title: Cyber Assured Systems Engineering (CASE) ***Description:*** The Cyber Assured Systems Engineering (CASE) program aims to enable the systematic design of networked cyber physical systems to be resilient against cyberattacks. The current state-of-practice for cyber resilience utilizes penetration testing after system construction to drive post-design re-engineering. The CASE technical approach is 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	-	-	17.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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. CASE builds on technology developed in the High Assurance Cyber Military Systems program. ***FY 2018 Plans:*** - Develop techniques to derive resilience-related requirements before system design and construction. - Develop architectural design and analysis tools to design-in derived resilience requirements while providing feedback to the human designer to allow for sensible tradeoffs between resilience and other system design goals. - Formulate cyber resilience design challenge problems relevant to military cyber physical systems. - Explore the potential for using formal methods to enable secure network interactions. - Create tools to adapt existing software to support system-level resilience requirements and inference engines, satisfiability solvers, and provers scalable to complex cyber physical systems. - Develop techniques for translating the output of cyber resilience design tools into concepts relevant to the system designer. - Demonstrate and evaluate design tools and techniques on an initial cyber resilience design challenge problem. - Initiate development of provably secure, maintainable open source versions of fully-featured, highly-performance, network infrastructure.			
Title: Automated Cyber Operations and Defense (ACOD) ***Description:*** The Automated Cyber Operations and Defense (ACOD) program will develop a semi-automated cyber operations system to enable operators to detect and respond to cyber attacks more rapidly than unaided human operators. The ACOD 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. As with algorithmic trading of financial instruments, the program envisions high-intensity cyber operations conducted by computers under human supervision. To accomplish this, ACOD 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. Through human-machine cyber teaming, ACOD will ensure U.S. operational superiority across the spectrum of cyber conflict. ***FY 2018 Plans:*** - Explore techniques for assessing the presence and seriousness of cyber vulnerabilities in new or existing software systems, enterprise networks and server configurations. - Develop concepts of operations for mixed-initiative cyber operations. - Design a cyber operations reasoning framework that a machine can use to determine which possible actions are allowable under rules of engagement; to rank alternative allowable actions in terms of likely efficacy; and to decide when an action may proceed.	-	-	12.257

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Propose interface strategies that facilitate timely human understanding of rapid changes in the cyber battlespace and effective human interaction with computerized cyber defenders. - Identify and tailor automation modes appropriate for use across the cyber conflict spectrum.			
Title: Cyber-Hunting at Scale (CHASE) ***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. The nature of the threat should be used to determine which data and analyses are required. 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 is 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 and summary cyber data and construct feature sets for indicators of adversary activity. - Formulate mathematical approaches for developing data collection, transmission and retention policies. - Develop initial distributed algorithms to enhance enterprise-scale cyber situational awareness.	-	-	18.054
Title: High Assurance Cyber Military Systems ***Description:*** The High Assurance Cyber Military Systems (HACMS) program is developing and demonstrating 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 may be within reach at reasonable costs. The program will develop, mature, and integrate these technologies to produce an embedded computing platform that provides a high level of assurance for mission-critical military applications. Additionally, the program will explore 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. ***FY 2016 Accomplishments:***	20.475	12.974	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Applied an architecture-based approach to high-assurance system development, enabling an effective cyber retrofit for a number of vehicles including a military helicopter and a military transport vehicle. - Demonstrated machine-tracked assurance cases for system-wide security properties on targeted vehicles, and increased the level of automation of proof generation in theorem provers. - Demonstrated the effectiveness of approaches by conducting penetration-testing exercises on the targeted vehicles. ***FY 2017 Plans:*** - Formulate assurance cases for complex mission critical systems that are comprised of multiple interacting components.			
Title: Vetting Commodity Computing Systems for the DoD (VET) ***Description:*** The Vetting Commodity Computing Systems for the DoD (VET) program is developing 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 will detect hidden malicious functionality and also enable the detection of software and firmware defects and vulnerabilities that can facilitate adversary cyber attack. ***FY 2016 Accomplishments:*** - Measured probabilities of false- and missed-detection, and human analysis time to identify new techniques that are likely candidates for integration into an end-to-end DoD vetting application. - Conducted an integrated end-to-end software/firmware-vetting technology demonstration relevant to potential transition partners. - Initiated an effort to apply VET technologies to naval industrial control environments. ***FY 2017 Plans:*** - Run comparative performance evaluations between program-developed vetting tools and commercially available tools. - Engage in experiments and pilot deployments of prototype tools with transition partners on software of interest to DoD. - Based on user feedback, make improvements to prototypes to enhance usability in the context of vetting software for DoD.	22.625	13.520	-
Title: Cyber Grand Challenge (CGC) ***Description:*** The Cyber Grand Challenge (CGC) program is creating automated defenses that can identify and respond to cyber attacks more rapidly than human operators. CGC technology will monitor defended software and networks during operations, reason about flawed software, formulate effective defenses, and deploy defenses automatically. Technologies to be developed and integrated may include anomaly detection, Monte Carlo input generation, case-based reasoning, heuristics, game theory, and stochastic optimization. The CGC capability is needed because highly-scripted, distributed cyber attacks exhibit speed,	11.329	6.556	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
complexity, and scale that exceed the capability of human cyber defenders to respond in a timely manner. DARPA will incentivize competition through a Grand Challenge in which CGC technologies compete head-to-head. Initial funding for this effort was provided in Project IT-05. Additional funding is being provided in IT-03 to enable the creation of the more robust competition infrastructure necessary to accommodate the large number of competitors. ***FY 2016 Accomplishments:*** - Prepared automated systems for final competition via a multi-month series of audited trials. - Conducted world's first automated computer security contest: Cyber Grand Challenge Final Event. - Released event results as cyber research corpus to measure and challenge future automated cyber capabilities. ***FY 2017 Plans:*** - Capture the lessons learned from the Cyber Grand Challenge Final Event to inform the design of future automated systems capable of engaging human experts. - Benchmark and baseline the abilities of expert reverse engineers to guide the creation of a machine-vs-expert evaluation corpus. - Formulate an infrastructure that allows for distributed machine-vs-expert engagements.			
Title: Active Cyber Defense (ACD) ***Description:*** The Active Cyber Defense (ACD) program developed technologies to enable DoD cyber operators to leverage inherent home field advantage when defending the DoD cyber battlespace. In the cyber environment, defenders have detailed knowledge of, and unlimited access to, the system resources that attackers wish to gain. The ACD program developed technologies to facilitate the conduct of defensive operations that involve immediate and direct engagement between DoD cyber operators and sophisticated cyber adversaries. Through these active engagements, DoD cyber defenders will be able to more readily disrupt, counter, and neutralize adversary cyber tradecraft in real time. Moreover, ACD-facilitated operations should cause adversaries to be more cautious and increase their work factor by limiting success from their efforts. ***FY 2016 Accomplishments:*** - Completed integration of system platforms and demonstrated capabilities to transition partners. - Performed final test and evaluation of integrated capabilities and secured partners for operational deployment. - Supported efforts to deploy capability to DoD and other U.S. Government cyber operators.	6.270	-	-
Title: Clean-slate design of Resilient, Adaptive, Secure Hosts (CRASH) ***Description:*** The Clean-slate design of Resilient, Adaptive, Secure Hosts (CRASH) program developed cyber security technologies using the mechanisms of biological systems as inspiration for radically re-thinking basic hardware and system designs. Higher level organisms have two distinct immune systems: the innate system is fast and deadly but is only effective	6.100	-	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
against a fixed set of pathogens; the adaptive system is slower but can learn to recognize novel pathogens. Similarly, CRASH developed mechanisms at the hardware and operating system level that eliminated known vulnerabilities exploited by attackers. However, because novel attacks will be developed, CRASH also developed software techniques that allowed a computer system to defend itself, to maintain its capabilities, and even heal itself. Finally, biological systems show that diversity is an effective population defense; CRASH developed techniques to make each computer system appear unique to the attacker and allow each system to change over time. ***FY 2016 Accomplishments:*** - Transitioned symbiotes capability (secure code structures embedded in device firmware that can provide a variety of cyber defense functions) to Air Force and Navy. - Transitioned microprocessor instruction set architecture security extensions to commercial processor designer.			
Title: Mission-oriented Resilient Clouds (MRC) ***Description:*** The Mission-oriented Resilient Clouds (MRC) program created technologies to enable cloud computing systems to survive and operate through cyber attacks. Vulnerabilities found in current standalone and networked systems can be amplified in cloud computing environments. MRC addressed this risk by creating advanced network protocols and new approaches to computing in potentially compromised distributed environments. Attention focused on adapting defenses and allocating resources dynamically in response to attacks and compromises. MRC resulted in new approaches to measure trust, reach consensus in compromised environments, and allocate resources in response to current threats and computational requirements. MRC developed new verification and control techniques for networks embedded in clouds that must function reliably in complex adversarial environments. ***FY 2016 Accomplishments:*** - Collaborated with Defense Information Systems Agency in evaluating prioritized- and guaranteed-delivery enhancements to commercial networking technologies. - Collaborated with Naval Sea Systems Command on techniques to authenticate multicast packets on networked cyber physical systems on ships.	4.500	-	-
Accomplishments/Planned Programs Subtotals	209.557	255.137	260.757

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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*

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
IT-04: *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*	-	46.508	56.039	82.108	-	82.108	84.915	88.842	79.936	87.921	-	-

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 operate safely with high degrees of autonomy. The technologies developed in this project will be applied to intelligence analysis, command and control, cyberspace operations, electronic warfare, and robotics.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Low Resource Languages for Emergent Incidents (LORELEI)	22.225	25.907	31.574
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 2016 Accomplishments: - Developed initial techniques for quantifying the linguistic similarity of language usage in diverse documents and media. - Developed initial algorithms to exploit the universal properties of languages when rapidly ramping up for a low-resource language. - Developed semantic techniques for identifying the common topics, themes, and sentiment in speech and text in diverse foreign languages.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Collected, generated, and annotated data for an initial set of resources in typologically representative medium-resource languages. - Created a baseline toolkit to rapidly develop an initial situational awareness capability given a new low-resource language document collection. ***FY 2017 Plans:*** - Develop means to determine opinions and beliefs in low-resource languages. - Construct an integrated system employing multiple algorithms for low-resource language analysis. - Develop the user interface platform that will provide native speaker information to the analysis platform and provide query-driven information to the users. - Evaluate the performance of the analysis algorithms on new languages and measure progress on the languages evaluated in the previous year. ***FY 2018 Plans:*** - Extend development of means to determine opinions and beliefs in low-resource languages in speech signals as well as text. - Integrate multiple new algorithms for low-resource language analysis with a graphical user interface and evaluate the interface platform with end users. - Evaluate the performance of the analysis algorithms on new languages and measure progress on the languages evaluated in the previous year.			
Title: Deep Exploration and Filtering of Text (DEFT)	18.762	13.632	9.394
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 will extract knowledge at scale for open source intelligence and threat analysis. Transition partners include the intelligence community and operational commands. ***FY 2016 Accomplishments:*** - Improved algorithm performance on current functions and extended single-document algorithms to function across multiple documents. - Merged and optimized combined output of algorithms focused on different tasks such as belief and sentiment extraction, event argument and attribute identification, and relation mapping.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Developed methods for evaluating the effectiveness of various natural language processing algorithms in a multi-lingual environment, including evaluation of sentiment and belief analysis. - Transitioned additional component prototypes to end-user sites for effectiveness assessment. ***FY 2017 Plans:*** - Develop algorithms to detect sub-events and identify their relationships to main events. - Evaluate the accuracy and effectiveness of language processing in specific foreign languages. - Develop algorithms to combine information from multiple language sources. - Transition a multi-lingual system-level prototype to end-user sites for effectiveness assessment. ***FY 2018 Plans:*** - Develop techniques to integrate diverse information from multiple intelligence sources into a uniform schema amenable to machine reasoning and human collaboration. - Develop reasoning strategies capable of identifying information gaps, reconciling conflicting information, and proposing the most likely completions for partially specified knowledge. - Optimize techniques and prototypes based on feedback from operational users.			
Title: Explainable Artificial Intelligence (XAI)* ***Description:*** *Previously Understanding Machine Intelligence (UMI) 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 2017 Plans:*** - Formulate approaches for AI systems to explain their behavior and clarify the basis for and reliability of outputs. - Propose a general interface technology that communicates the internals of machine learning models in a human-interpretable fashion.	-	11.000	23.840

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Explore designs for a complete explainable AI system that consists of explainable machine learning models and an explanation generation interface. - Explore approaches for autonomous planning and execution of tasks based on high level goals and constraints. ***FY 2018 Plans:*** - Develop and demonstrate an initial prototype of an explainable AI system using modified deep learning techniques to produce deep neural nets that are more interpretable than current techniques. - Develop and demonstrate an initial prototype of an explainable AI system using structured, causal machine learning techniques that are inherently more interpretable. - Develop and demonstrate an initial prototype of a system that creates an explainable model for an existing black box machine learning system. - Integrate artificial intelligence and robust control techniques to ensure predictable and trustable autonomous operations in uncertain and adversarial environments. - Formulate perceptually-grounded representations to enable commonsense reasoning by machines about the physical world and spatio-temporal phenomena. - Explore quantitative approaches for creating human-computer teams through the inclusion of individuals and computers/ autonomous systems with complementary characteristics/capabilities.			
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 explicit alternative interpretations of events, situations, and trends from a variety of unstructured sources, for use in an environment where there are noisy, conflicting, and potentially deceptive data. 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. When these independent, impoverished analyses are combined, generally late in the analysis process, the result can be a single apparent consensus view that does not reflect a true consensus. To overcome these limitations, AIDA seeks to research, develop, and demonstrate technology capable of automatically mapping information derived from multiple sources into a common semantic representation, aggregating information, resolving ambiguities, discovering conflicting information, and generating and exploring multiple interpretations of events, situations, or trends of interest. If successful, AIDA will provide decision makers a capability to understand alternatives and make contingency plans accordingly. Transition partners include operational commands and the intelligence community. AIDA builds on technology developed in the Deep Exploration and Filtering of Text program. ***FY 2017 Plans:*** - Develop an initial semantic representation language for a common semantic representation from diverse sources.	-	5.500	17.300

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Adapt multimedia-analysis algorithms to produce information suitable for use in a common semantic representation and to accept and utilize information from the common semantic representation or from the generated interpretations. - Explore semantic techniques that automatically generate, update, rank, and prune alternative interpretations as they become more or less likely given incoming data streams. ***FY 2018 Plans:*** - Develop techniques to integrate diverse information from multiple sources into a uniform schema amenable to machine reasoning and human collaboration. - Develop techniques to extend known ontologies using information from diverse sources. - Develop techniques to estimate the confidence of the generated interpretations considering accuracy of the analysis, provenance, and source veracity. - Develop techniques to quantify the possibility that an interpretation is based on semantically consistent misinformation injected by an adversary.			
Title: Robust Automatic Transcription of Speech (RATS) ***Description:*** The Robust Automatic Transcription of Speech (RATS) program developed robust speech processing techniques for conditions in which speech signals are degraded by distortion, reverberation, and/or competing conversation. Robust speech processing technologies enable soldiers to hear or read clear English versions of what is being said in their vicinity, despite a noisy or reverberant environment. Techniques were developed for speech activity detection, language identification, speaker identification, and keyword spotting. RATS technology was optimized on real world data in conjunction with several operational users. ***FY 2016 Accomplishments:*** - Developed, integrated and tested techniques to deal with multiple speakers and overlapping speaker channels. - Developed unified Application Programming Interface to support multiple tactical integration platforms. - Integrated technologies into multiple transition partner platforms and operations.	5.521	-	-
Accomplishments/Planned Programs Subtotals	46.508	56.039	82.108

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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*

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	Project (Number/Name) IT-05 / *CYBER TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
IT-05: *CYBER TECHNOLOGY*	-	41.422	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Cyber Technology project developed technology to increase the security of military information systems and the effectiveness of cyber operations. Over the past decade the DoD has embraced net-centric warfare by integrating people, platforms, weapons, sensors, and decision aids. Adversaries seek to limit this force multiplier through cyber attacks intended to degrade, disrupt, or deny military computing, communications, and networking systems. Technologies developed under the Cyber Technology project ensured DoD net-centric capabilities survive adversary cyber attacks and will enable new cyber-warfighting capabilities. Promising technologies will transition to system-level projects.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Plan X	32.362	-	-
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. Plan X funding continues in FY 2017 in Project IT-03. ***FY 2016 Accomplishments:*** - Published application store software development kit and integrated third party cyber capabilities. - Refined analytics features for battlespace, courses of action analysis, and planning subsystems. - Adopted and integrated security access and use privileges, and demonstrated large-scale deployment of the end-to-end system with users in disparate locations. - Integrated with existing military cyber threat/intel systems to allow bidirectional flow of data to and from Plan X to provide visualization and insights into the cyber battlespace. - Released Plan X 2.0 system and field tested capabilities at Cyber Guard/Cyber Flag 2016, and initiated technology transition with U.S. Army Cyber Command (ARCYBER) and U.S. Army Program Executive Office, Enterprise Information Systems (PEO EIS).			
Title: Cyber Grand Challenge (CGC)	9.060	-	-
Description: The Cyber Grand Challenge (CGC) program is creating automated defenses that can identify and respond to cyber attacks more rapidly than human operators. CGC technology will monitor defended software and networks during operations,			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-05 / *CYBER TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
reason about flawed software, formulate effective defenses, and deploy defenses automatically. Technologies to be developed and integrated may include anomaly detection, Monte Carlo input generation, case-based reasoning, heuristics, game theory, 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 will incentivize competition through a Grand Challenge in which CGC technologies compete head-to-head. The CGC program is also funded in Project IT-03. ***FY 2016 Accomplishments:*** - Prepared automated systems for final competition via a multi-month series of audited trials. - Conducted world's first automated computer security contest: Cyber Grand Challenge Final Event. - Released final event results as cyber research corpus to measure and challenge future automated cyber capabilities.			
Accomplishments/Planned Programs Subtotals	41.422	-	-

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	24.682	21.250	13.014	-	13.014	13.469	14.346	14.346	14.346	-	-
BW-01: *BIOLOGICAL WARFARE DEFENSE*	-	24.682	21.250	13.014	-	13.014	13.469	14.346	14.346	14.346	-	-

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 program 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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	24.265	21.250	11.014	-	11.014
Current President's Budget	24.682	21.250	13.014	-	13.014
Total Adjustments	0.417	0.000	2.000	-	2.000
• 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	1.190	0.000			
• SBIR/STTR Transfer	-0.773	0.000			
• TotalOtherAdjustments	-	-	2.000	-	2.000

Change Summary Explanation

FY 2016: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2017: N/A
FY 2018: Increase reflects program repricing in Defense Against Mass Terror Threats.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
Title: Defense Against Mass Terror Threats	14.732	14.168	13.014
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 a nuclear attack. Challenges in reducing U.S. vulnerability to a nuclear attack include monitoring radiation levels and exposure in urban areas and mitigating the lethal short- and long-term effects of ionizing radiation. A major goal of this program is to develop new sensors and sensing networks that can economically and reliably provide wide-area monitoring of radionuclide signatures. ***FY 2016 Accomplishments:*** - Developed high performance radiation detectors for wide-area monitoring and implemented novel manufacturing approaches for low-cost production. - Developed and studied concepts-of-operations for wide-area radiation monitoring networks. ***FY 2017 Plans:*** - Optimize system models and detection algorithms utilizing multiple sensor inputs for wide-area monitoring of radiation. - Integrate detection algorithms with high performance radiation detectors to form a sensor network for wide-area monitoring. - Demonstrate a wide-area, radiation monitoring, sensor network at large scale through simulation and representative pilot data collections. ***FY 2018 Plans:*** - Refine system features and functionality of sensor network based on pilot data collections and user feedback. - Demonstrate, operationalize, and transition full-scale monitoring capability with operational partner.			
Title: Medical Countermeasures	9.950	7.082	-
Description: To further develop an expedited medical countermeasure capability, emerging technologies will be integrated to address 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 will also be focused on reduction of time, risk, and costs associated with new therapeutic development. For example, this program will develop 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. ***FY 2016 Accomplishments:*** - Demonstrated an expanded set of IVTCs able to reproduce the function of seven human physiological systems. - Designed and built additional modules that are compatible with the expanded set of IVTCs and enable the platform to sustain the integrated IVTCs for three weeks.			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
- Demonstrated that the expanded set of seven IVTCs individually responded and reacted to test compounds in a manner consistent with the known effects of those compounds on the corresponding human tissues. - Demonstrated that a modular arrangement of the expanded set of seven IVTCs can be used to predict the absorption, distribution, metabolism and elimination that the test compounds are known to exhibit in human physiological systems. ***FY 2017 Plans:*** - Demonstrate an expanded set of IVTCs able to reproduce the function of ten human physiological systems. - Design and build additional modules that are compatible with the expanded set of IVTCs and enable the platform to sustain the integrated IVTCs for four weeks. - Demonstrate that the expanded set of ten IVTCs individually respond and react to test compounds in a manner consistent with the known effects of those compounds on the corresponding human tissues.			
Accomplishments/Planned Programs Subtotals	24.682	21.250	13.014

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	289.371	313.843	343.776	-	343.776	363.482	369.687	388.716	390.376	-	-
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	52.948	43.024	33.544	-	33.544	41.765	34.451	23.451	41.451	-	-
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	61.041	52.847	92.675	-	92.675	91.503	99.283	129.283	111.283	-	-
TT-06: *ADVANCED TACTICAL TECHNOLOGY*	-	10.912	6.500	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
TT-07: *AERONAUTICS TECHNOLOGY*	-	36.009	62.876	67.378	-	67.378	67.518	62.528	49.528	49.528	-	-
TT-13: *INFORMATION ANALYTICS TECHNOLOGY*	-	128.461	148.596	150.179	-	150.179	162.696	173.425	186.454	188.114	-	-

A. Mission Description and Budget Item Justification

This 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 focuses on broad technology areas including compact, efficient, frequency-agile, diode-pumped, solid-state lasers for infrared countermeasures, laser radar, holographic laser sensors, communications, and high-power laser applications.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*

Aeronautics Technology efforts 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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	302.582	313.843	381.964	-	381.964
Current President's Budget	289.371	313.843	343.776	-	343.776
Total Adjustments	-13.211	0.000	-38.188	-	-38.188
• 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	-3.575	0.000			
• SBIR/STTR Transfer	-9.636	0.000			
• TotalOtherAdjustments	-	-	-38.188	-	-38.188

Change Summary Explanation

FY 2016: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2017: N/A
FY 2018: Decrease reflects rephasing of several Naval Warfare Technology and Aeronautics Technology programs.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	52.948	43.024	33.544	-	33.544	41.765	34.451	23.451	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 2016	FY 2017	FY 2018
Title: Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES)	31.845	32.024	33.544

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 2016 Accomplishments:
- Determined Point of Departure (POD) designs.
- Completed end-to-end modeling and simulation of POD designs.
- Began risk reduction tests and prototyping.
- Updated models and simulations as designs were modified.
- Conducted risk reduction subsystem tests to verify gun hardening and performance.
- Performed wind tunnel tests to validate aerodynamic models and air gun test to verify gun-launch.

FY 2017 Plans:
- Update models and simulations of select designs.
- Complete preliminary prototype design.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Mature electronics packaging through design and subsystem validation. - Conduct gun launch and fire solid rocket motors to validate projectile kinematic performance. - Perform initial controlled projectile flight tests to assess projectile maneuver performance. ***FY 2018 Plans:*** - Finalize designs for major subcomponents. - Demonstrate gun survivability for all up projectile. - Conduct ballistic and controlled test vehicle flights. - Apply lessons learned from flight tests to maturing design.			
Title: Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV)	6.840	6.000	-
Description: The Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV) program has 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. By establishing the premise that a human is never intended to step on board at any point in the operational cycle, ACTUV concepts can take advantage of an unexplored design space that eliminates or modifies conventional manned ship design constraints in order to achieve disproportionate speed, endurance, and payload fraction. The resulting unmanned naval vessels must possess sufficient situational awareness and autonomous behavior capability to operate in full compliance with the rules of the road and maritime law to support safe navigation for operational deployments spanning thousands of miles and months of time. When coupled with innovative sensor technologies, the ACTUV system provides 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 include unmanned naval vessel design methodologies, ship system reliability, high fidelity sensor fusion to provide an accurate 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. ***FY 2016 Accomplishments:*** - Completed construction of prototype vessel. - Initiated at-sea testing to validate baseline performance of vessel, sensor systems, and autonomy. - Moved the vessel from the contractor facility to a Navy facility in San Diego for long term testing with the Office of Naval Research (ONR). - Demonstrated improved situational awareness and autonomy capabilities, incorporating advanced above water sensors. - Demonstrated the ability to successfully integrate a new mission payload, Towed Airborne Lift of Naval Systems (TALONS). ***FY 2017 Plans:***			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Demonstrate the ability to successfully integrate new mission payloads, including a Mine Counter Measures (MCM) payload and a Mechanically Uncoupled Stereo (MUSE) camera system. - Continue vessel at-sea testing, including tactical exercises with fleet units. - Continue testing of new payloads for MCM, ASW, and other missions. - Transition custody of prototype vessel to the Navy (ONR).			
Title: Upward Falling Payloads (UFP) ***Description:*** The goal of the Upward Falling Payloads (UFP) program is to develop forward-deployed unmanned distributed systems that could provide non-lethal effects or situational awareness over large maritime environments. Building upon and complimenting concepts for maritime situational awareness and Intelligence, Surveillance and Reconnaissance (ISR) developed under the DASH program, budgeted in PE 0603766E, Project NET-02, the UFP approach centers on pre-deploying deep-ocean nodes years in advance in forward operating areas which could be commanded from standoff to launch to the surface. ***FY 2016 Accomplishments:*** - Developed and demonstrated scalable riser prototype with launch of payload surrogate from surfaced riser. - Demonstrated deep-ocean, short-duration submergence of full-scale riser prototype followed by triggered release and ascent to surface. - Demonstrated long-range acoustic communications sufficient to wake up a UFP node. - Developed and analyzed hardware interface and long range acoustic communications for triggered release of riser from existing undersea cable. ***FY 2017 Plans:*** - Complete analysis of long range underwater acoustic communications test data for triggering riser.	14.263	5.000	-
Accomplishments/Planned Programs Subtotals	52.948	43.024	33.544

C. Other Program Funding Summary ($ in Millions)

Line Item	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
• ACTUV: *Office of Naval Research MOA*	7.340	8.807	3.917	-	3.917	0.000	0.000	0.000	0.000	-	-

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-03 / *NAVAL WARFARE 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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	61.041	52.847	92.675	-	92.675	91.503	99.283	129.283	111.283	-	-

A. Mission Description and Budget Item Justification

This 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 2016	FY 2017	FY 2018
Title: Squad X	38.600	31.410	36.675

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 2016 Accomplishments:

- Completed systems architecture, technology evaluation, and experimentation trade studies.
- Completed Squad X Baseline experimentation, through live experimentation, to obtain a system performance baseline for a currently-equipped, U.S. Army rifle squad.
- Refined technology development efforts focusing on squad precision effects, non-kinetic engagement, enhanced sensor fusion and exploitation, and squad collaborative autonomy.
- Matured modeling and simulation environment to improve representation of tactics and operational realism in order to allow for an overarching iterative design process and squad system performance estimation.
- Leveraged Squad X testbed and simulation environments to iteratively assess developed technology and architecture schemes.
- Demonstrated initial individual technology capabilities in technology assessments.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Concluded Tactical Edge Standards Boards. ***FY 2017 Plans:*** - Leverage Squad X testbed and simulation environments to iteratively assess developed technology and architecture schemes. - Leverage virtual testbed to provide predictions of system performance in multiple operational conditions. - Initiate planning for system-level experimentation and evaluation in relevant conditions with operational units. - Demonstrate through live experimentation individual technology capabilities for squad precision effects, non-kinetic engagement, enhanced sensor fusion and exploitation, and squad collaborative autonomy in simulated operational environments. - Initiate technology development efforts focusing on human machine interfaces, the squad common operating picture, and the synchronization of kinetic and non-kinetic engagement capabilities. - Initiate squad-system development efforts focusing on automatic systems to increase squad performance and the integration of previously developed technologies to enhance dismounted operations. ***FY 2018 Plans:*** - Complete virtual testbed development and utilize testbed to support system-level experimentation and evaluation. - 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, 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.			
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 2016 Accomplishments:*** - Completed trades of mission/vignette-driven collaborative command and control of a MI unit composed of a warfighter team and semi-autonomous systems. - Completed trade studies and initial estimates of perception and autonomous algorithms required to match vignettes.	4.541	4.000	5.000

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Completed trade studies of candidate platforms and options for conversion, system integration, interfaces (electrical, mechanical, software, etc.), and define preliminary warfighter architectures to leverage. ***FY 2017 Plans:*** - Initiate technology development efforts for critical perception and autonomous algorithms to enable semi-autonomous systems to act as force multipliers for warfighter team. - Initiate technology development efforts for critical collaborative behavior algorithms to enable semi-autonomous systems to cooperatively execute missions without human interaction. - Initiate technology development efforts for critical technologies to enable effective command and control of manned and unmanned warfighter team. ***FY 2018 Plans:*** - Continue technology development efforts for critical perception and autonomous algorithms to enable semi-autonomous systems to act as force multipliers for warfighter team. - Continue technology development efforts for critical collaborative behavior algorithms to enable semi-autonomous systems to cooperatively execute missions without human interaction. - Continue technology development efforts for critical technologies to enable effective command and control of manned and unmanned warfighter team. - Evaluate integrated technologies in relevant environments with single vehicle and section-level experiments.			
Title: Mobile Force Protection (MFP) ***Description:*** *Previously Counter Unmanned Air System (C-UAS) and Force Protection (CFP) 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 2017 Plans:*** - Define system level requirements, and conduct trade studies.	-	12.400	31.000

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Develop interfaces with the program mandated government owned open architecture (GOOA). - 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 neutralization techniques. ***FY 2018 Plans:*** - Conduct 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 enable rapid relocation by reducing size, weight and power. - Develop new interfaces and integrate novel algorithms in the GOOA to reduce manning, false alarm rate, and reaction time. - Update affordability and cost analysis.			
Title: Precision Light Strike Munition (PLSM) ***Description:*** The Precision Light Strike Munition (PLSM) program will seek to develop a small, lightweight, shoulder-launched, guided missile weapon for the individual warfighter. Current short-range weapons are used against a variety of target sets using different munitions and launchers without the benefit of active guidance. Current long-range weapons in support of dismounted operations are highly effective against a specific target set at range, but come with a heavy physical burden, high cost per shot/ procurement cost, and often require teams of operators (sometimes dedicated) for employment. The program goal is to improve on the existing, lightweight unguided missile systems by increasing range, accuracy, and lethality, while reducing cost. The program will also explore improvement of existing platform gun systems by leveraging advances in miniaturization, precision guidance and warheads. PLSM seeks to take advantage of commercial technologies to provide a low-cost, multi-use, and multi-function precision engagement capability. The PLSM program could significantly increase the combat power of small units with reduced physical burden, while significantly reducing cost relative to near-peer and peer adversaries. ***FY 2018 Plans:*** - 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.	-	-	10.000
Title: Urban Operations ***Description:*** The goal of the Urban Operations program is to generate capabilities which would allow distributed forces to operate effectively in dense urban areas (e.g. megacities). Enabling capabilities would focus on enhanced tactical situational	-	-	10.000

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
awareness, precise control of destructive and non-destructive effects, network operability and resilience, cyber- and electronic warfare robustness, freedom of movement, and agile logistic sustainment. The Urban Operations system would encompass sub-system and platform technologies supporting tactical mobility, operational endurance, precision effects, extensive command and control, and enhanced protection for ground forces across the range of conflicts in highly populated, densely built-up areas. Key operational functions and mission capabilities would make significant use of unmanned and autonomous systems. ***FY 2018 Plans:*** - Identify critical operational needs, tactical and environmental issues and key measures of effectiveness. - Conduct trade space analysis and develop overall system architecture. - Identify and begin development of foundational component technologies. - Develop system and command and control (C2) concepts of operation/employment (CONOPS/CONEMPS).			
Title: Ground Experimental Vehicle (GXV)	17.900	5.037	-
Description: The goal of the Ground Experimental Vehicle (GXV) program is to investigate ground vehicle technologies that enable crew/vehicle survivability through means other than traditional heavy passive armor solutions. This will be accomplished through research and development of novel ground combat and tactical vehicle technology solutions that demonstrate significantly advanced platform mobility, agility, and survivability. The focus of the GXV program will be on technology development across multiple areas to simultaneously improve military ground vehicle survivability and mobility. Traditionally, survivability and mobility have to be traded against each other due to the reliance on heavy armor. The GXV program seeks to break this trend. Coupled with the development of technologies, the GXV program will define concept vehicles which showcase these developmental technologies. A modeling and simulation effort will also be undertaken to understand the vehicle design trade space for the concept vehicles using the developmental technologies and to illustrate how these vehicles might be used operationally in combat scenarios. Technology development areas are likely to include increasing vehicle tactical mobility, survivability through agility, and crew augmentation, though other relevant technologies may also be pursued. ***FY 2016 Accomplishments:*** - Continued GXV technology development efforts focused on increasing mobility, survivability through agility and crew augmentation. - Matured parametric models for evaluating military utility of technologies. - Completed studies focusing on system trades relating to system power requirements, size/caliber of weapon systems, and crew size. - Initiated studies focusing on the impact of crew augmentation capabilities on the size and cognitive workload of combat vehicle crews.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Conducted survivability analysis of individual concepts. ***FY 2017 Plans:*** - Complete development of parametric models for evaluating military utility of technologies. - Complete studies focusing on the impact of crew augmentation capabilities on the size and cognitive workload of combat vehicle crews. - Complete additional survivability analyses of individual concepts. - Complete GXV technology development efforts focused on increasing mobility and survivability through agility and crew augmentation.			
Accomplishments/Planned Programs Subtotals	61.041	52.847	92.675

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
TT-06: *ADVANCED TACTICAL TECHNOLOGY*	-	10.912	6.500	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

This project focuses 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 2016	FY 2017	FY 2018
Title: Laser Ultraviolet Sources for Tactical Efficient Raman (LUSTER)	8.000	6.500	-
Description: The Laser Ultraviolet Sources for Tactical Efficient Raman (LUSTER) program is developing a compact laser suitable for a wide array of DoD applications, such as sensing the presence of chemical agents. The program aims to develop a semiconductor laser that emits deep ultraviolet (UV) radiation with high efficiency, high laser purity, and an output power over one watt. This would represent 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. ***FY 2016 Accomplishments:*** - Optimized laser epitaxial material, electron-beam source, and frequency multiplying nonlinear crystals for higher efficiency and high power operation. - Developed compact low power electronics for driving and controlling photonic and mechanical components. - Demonstrated first electrically injected UV light-emitting diode (LED) at 237nm. - Demonstrated record UV emission of 213mW from an electron-beam pumped semiconductor chip. - Demonstrated record output power of >2W from a Gallium Nitride based tapered amplifier blue laser. ***FY 2017 Plans:*** - Demonstrate bench top deep UV laser system that meets final metrics of > 100 mW output power, >4% efficiency, and line width <0.1 nm. - Demonstrate a path to meeting the Phase 2 metrics of > 1 W output power, 10% total system efficiency, line width less than 0.01 nm and size < 2 in^3.			
Title: Endurance	2.912	-	-
Description: The Endurance program developed laser technology to protect airborne platforms from emerging and legacy electro-optical/infrared (EO/IR) guided surface-to-air missiles. The Endurance system planned to have an open architecture, granting the flexibility to integrate different subsystems with varying capabilities. Endurance is an early application of technology			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-06 / *ADVANCED TACTICAL TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
developed through DARPA's Excalibur program and plans to transition to the Services. The applied research portion of the program focused on miniaturizing the component laser technologies, developing high-precision target identification and tracking, and making a lightweight, agile beam control system to engage high speed targets within the short times needed for aircraft self-defense. The program also focused on the phenomenology of laser-target interactions and associated threat vulnerabilities. An advanced technology component of this program, which focused on developing and testing various Endurance subsystems, is budgeted in PE 0603739E, Project MT-15. ***FY 2016 Accomplishments:*** - Conducted effects testing on an available surrogate of the key optical assembly of a seeker of a larger class of threat EO/IR guided surface-to-air missile and verified estimated lethality criteria to anchor lethality models. - Completed a live-fire test plan in conjunction with all the stakeholders (Government test team, performer, target logistics, range support, range safety and environmental offices, laser clearing house, etc.). - Completed missile trajectory simulations for each threat class from many possible launch locations and pod test locations to support risk reduction for the advanced technology component testing. - Partially-packaged high-power laser for pod-integration testing.			
Accomplishments/Planned Programs Subtotals	10.912	6.500	-

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-07 / *AERONAUTICS TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
TT-07: *AERONAUTICS TECHNOLOGY*	-	36.009	62.876	67.378	-	67.378	67.518	62.528	49.528	49.528	-	-

A. Mission Description and Budget Item Justification

Aeronautics Technology efforts 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Aircrew Labor In-cockpit Automation System (ALIAS)	13.213	22.876	19.378

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 onboard 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 2016 Accomplishments:
- Performed ground demonstration of ALIAS system mission functionality and contingency management.
- Conducted flight demonstration of perception and actuation subsystems and new command interface.
- Demonstrated portability to new aircraft type.
- Continued risk reduction activities.

FY 2017 Plans:
- Conduct flight demonstration of integrated capabilities.
- Perform ground demonstration of portability timeline into other aircraft.
- Initiate airworthiness evaluation for integrated flight demonstration on operational aircraft.
- Initiate commercial certification process of ALIAS.

FY 2018 Plans:
- Demonstrate knowledge acquisition timeline and kit installation/removal on other aircraft.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- 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.			
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 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 2016 Accomplishments:*** - Conducted exploratory trade studies to establish feasibility of technical approaches. - Initiated studies on integration with existing Service systems and systems architectures. - Conducted system concept design tradeoff analyses. ***FY 2017 Plans:*** - Conduct conceptual design and system requirements review of demonstration system. - Initiate engineering design of integrated demonstration concepts. - Conduct system and subsystem risk reduction test planning. - Develop objective system concepts and mission capability projections. ***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 flight test of demonstration system components.	17.996	36.000	36.000
Title: Advanced Aeronautics Technologies ***Description:*** The Advanced Aeronautics Technologies program will examine and evaluate aeronautical technologies and concepts through applied research. These may include feasibility studies of novel or emergent materials, devices and tactics	4.800	4.000	2.000

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
for both fixed and rotary wing air vehicle applications, as well as manufacturing and implementation approaches. The areas of 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 2016 Accomplishments:*** - Performed modeling of concepts and architectures. - Conducted trade studies of emerging concepts. - Conducted study with military Service Academies (USNA, USAFA, USMA) utilizing a live-fly competition to examine swarm versus swarm unmanned aerial system (UAS) technologies and tactics. ***FY 2017 Plans:*** - Perform testing of enabling technology components. - Investigate tactically relevant concepts for swarm versus swarm unmanned aerial system (UAS) technologies. - Initiate conceptual system designs. ***FY 2018 Plans:*** - Conduct proof-of-concept technology demonstrations. - Investigate emerging technologies and conduct initial studies.			
Title: OFFensive Swarm-Enabled Tactics (OFFSET)	-	-	10.000
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 advanced mobility, distributed perception, distributed decision-making, and collaborative autonomy for large teams of unmanned systems, including unmanned ground, air, and/or maritime capabilities through the use of both virtual, game-based and physical, live-fly testbeds. Key research thrusts include the development of new platforms, sensors, and algorithms; advances in communication, networking, and autonomy; improvement of swarm logistics and concepts of employment; and development of human-swarm teaming interface technologies. These combined enhancements will enable employment of these collective systems to address current needs and defeat future threats. The program will consider technologies supporting U.S. ground, air, and maritime operations requiring organic and/or tactical swarm capabilities, leveraging low-cost, rapidly deployable, autonomous system technologies. ***FY 2018 Plans:*** - Perform initial trade studies of platform requirements to include range, payload, mobility, communications, and autonomy requirements - Assess technology maturity and predict technology trends to identify research and development needs and gaps. - Identify key technology advances required for swarm tactics concepts of deployment and employment.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Initiate research and development for integration of advanced sensors, mobility, communication, and command & control technologies.			
Accomplishments/Planned Programs Subtotals	36.009	62.876	67.378

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
TT-13: *INFORMATION ANALYTICS TECHNOLOGY*	-	128.461	148.596	150.179	-	150.179	162.696	173.425	186.454	188.114	-	-

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 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. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Media Forensics (MediFor)	17.000	22.500	28.879

Description: The Media Forensics (MediFor) program is creating technologies for analyzing diverse types of media content to determine their 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 trustworthiness of open source and captured images and video. Technologies will transition to operational commands and the intelligence community.

FY 2016 Accomplishments:
- Defined processes and practices for the scientific grounding of integrity of visual media, including detection of pixel level manipulations and inconsistencies in shadows/illumination and motion/trajectories.
- Collected images and videos for evaluation and training of algorithms.
- Designed evaluation paradigms for integrity assessment appropriate for adversary insertion/deletion actions.

FY 2017 Plans:
- Develop advanced techniques for media fingerprinting and for searching large repositories for content produced by the same device.
- Develop cross media representations of semantic content in image and video sources and techniques to indicate where the sources reinforce or contradict each other.
- Develop approaches for detecting commonly occurring media manipulations.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Create an integrated baseline platform for high performance forensic components. ***FY 2018 Plans:*** - Develop approaches to counter evolving media-editing technologies and to detect manipulation in noisy, degraded and highly compressed media. - 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 platform with graphical user interfaces (GUIs) for operator communication, and evaluate the platform independently and with selected government users.			
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 2016 Accomplishments:*** - Identified and further researched the most promising planning concepts, situation understanding concepts, and systems integrator. - Completed design of the overall DBM system, to include architecture, software components, CONOPS, and integration strategy for expected host platforms. - Implemented initial version of the integrated DBM system architecture, algorithms, and software. - Demonstrated initial version's capabilities in a simulated battle environment with impaired communications and loss of critical resources. ***FY 2017 Plans:*** - Update DBM algorithms and architecture based on experimentation to support complex contested environments. - Continue development of the DBM human-machine interface for battle management platforms and tactical platforms. - Demonstrate integrated DBM capabilities in live, virtual, and constructive simulations.	14.709	17.000	21.250

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Conduct software flexibility tests to demonstrate the ability to insert software upgrades without disrupting the BM structure. ***FY 2018 Plans:*** - 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.			
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 2016 Accomplishments:*** - Developed specialized search techniques for information discovery in networks of illicit activity. - Developed advanced content discovery, deep crawling, information extraction, and information relevance algorithms to support domain specific search. - Integrated and evaluated multiple end-to-end operational prototypes with automated and user-guided methods for web content analysis. - Conducted system evaluation with feedback from operational partners. - Transitioned capabilities for use in counter-human-trafficking operations and deep-web investigations. ***FY 2017 Plans:*** - Develop advanced domain search techniques and methods across the data pipeline (domain specification, crawlers, extractors, indexing, search, analytics, and visualization) that are domain agnostic, highly adaptable, and rapidly deployed.	22.492	17.920	9.460

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Develop integrated applications from Memex components demonstrating reduced time and increased flexibility of standing up new domain specific search capabilities with highly effective user experience. - Transition software components and integrated systems, and demonstrate enhanced support for partner missions. - Formulate approaches for optimizing big data analytics algorithms on reconfigurable hardware and create initial design for a combined software-hardware compiler (i.e., a software-hardware co-compiler). ***FY 2018 Plans:*** - Develop optimized components and integrated applications that address new domain specific search requirements arising from the national security and intelligence communities, and transition these to operational partners. - Establish and develop software and user communities around open source components and applications to ensure tool sustainment, software evolution, and long-term operational use. - Engineer runtime reconfigurable hardware and adaptive software that enables performance approaching that of custom hardware for data-intensive algorithms without need for redesign for specific algorithms and without sacrificing programmability.			
Title: Network Defense	28.874	17.500	6.750
Description: The Network Defense program is developing technologies to detect network attacks using network summary data. 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 2016 Accomplishments:*** - Developed algorithms that use scanning events to provide indications and warning of coordinated adversary activities. - Enhanced the persistent threat detection techniques and worked with potential users to identify threats particular to individual organizations/networks and/or shared by multiple organizations/networks. - Explored mathematical approaches for using summary information about an attack on one network to automatically detect similar attacks on other networks. - Demonstrated the feasibility of anticipating specific attack formats on one network based on attacks observed on other similar networks. ***FY 2017 Plans:*** - Optimize algorithms that detect anomalous behaviors and coordinated adversary activities, and test these through exercises, summary data and on-site evaluations.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Perform comprehensive test and evaluation of the multiple detection algorithms developed to produce quantitative understanding of probabilities of detection and false alarm and receiver operating characteristic curves for important classes of attacks. - Transition capabilities to U.S. government, defense industrial base organizations/networks, and other U.S. commercial companies. ***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, for example, where the attacker has varying degrees of insider knowledge. - Transition evolved capabilities to U.S. government, defense industrial base organizations and networks, and other U.S. commercial companies.			
Title: Causal Exploration of Complex Operational Environments* ***Description:*** *Formerly Predicting Complex Operational Environments The Causal Exploration of Complex Operational Environments program will develop 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 and among a wide variety of stakeholder groups. 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. The 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 will enable command staffs to design and quantitatively assess potential courses of action in complex operational environments. ***FY 2017 Plans:*** - Introduce and initiate development of an Intelligence, Surveillance, and Reconnaissance (ISR) collaboration environment that facilitates analyst assessments by enabling information discovery and workflow process sharing/reuse. - Develop information integration and scenario simulation frameworks to support mission design and planning for complex hybrid environments. - Develop appropriate schema for knowledge bases of entities typically encountered in an operational environment and their relationships.	-	19.050	25.600

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Develop dynamical systems models for projecting and predicting the interactions between diverse stakeholder groups that may have differing priorities, sensitivities and concerns. - Develop metrics for quantitative assessment of models including correctness and completeness of causal structure, ability to predict and explain known behavior, and quality and precision of model outputs. ***FY 2018 Plans:*** - Develop knowledge bases for the entities and their relationships in selected operational environments. - Develop displays for rapidly visualizing and evaluating likely outcomes of alternative U.S. mission designs. - Implement models and run simulations that are required to support the design of representative hybrid missions. - Integrate techniques in an initial prototype system and, in collaboration with operational and transition partners, initiate qualitative assessment of models for selected complex operational environments.			
Title: Data-Driven Discovery of Models (D3M) ***Description:*** The Data-Driven Discovery of Models (D3M) program, expanding on technical opportunities emerging from the XDATA 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, and the construction of empirical models that enable decision makers to predict behaviors and anticipate contingencies during tactical and strategic planning. The DoD and the Intelligence Community (IC) are fundamentally limited in this regard by a shortage of expert data scientists. 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 is automatically selectable, given data and an outcome; 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 2017 Plans:*** - Formulate automated approaches for hypothesizing relevant models/model components for a given outcome of interest and set of input data and for determining when apparent correlations are spurious. - Propose approaches for assessing alternative models by identifying which model(s) are most likely to generalize well in the presence of new data. - Design visualizations of data to help users understand the data underlying learned models and to make informed selections between alternative models. - Develop initial implementations of mechanisms for users to interact with models by mixing and matching model components. ***FY 2018 Plans:***	-	20.247	26.840

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Develop an initial library of modeling primitives that transform, structure, reduce, infer, augment, and model data, and a capability to compose modeling primitives into complex models. - Develop a collection of data science and empirical science problems with data and annotated code to enable automated learning. - Initiate development of an end-to-end, integrated virtual data scientist to 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.			
Title: Modeling Adversarial Activity (MAA)	-	10.000	16.400
Description: The Modeling Adversarial Activity (MAA) program will extend and apply techniques introduced in the Memex program to develop 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 promote or enable the development, procurement, possession, transport, and/or proliferation of WMTs and related capabilities. Monitoring and controlling WMT pathways is essential in 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 graph activity patterns with pathway models, and create synthetic data sets at scale to support development and testing of WMT pathway detection techniques. MAA research will be informed by interactions with the Defense Threat Reduction Agency (DTRA). ***FY 2017 Plans:*** - Formulate graph models for WMT pathway activity sequences designed by subject matter experts. - Explore computationally feasible approaches for aligning entities across multiple intelligence modalities and for approximate graph matching. - Collaborate with DTRA and additional potential transition partners on methods for generating synthetic activity data with realism adequate for testing WMT pathway recognition techniques. ***FY 2018 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.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Collaborate with DTRA and additional potential transition partners to implement techniques in their environments and to optimize techniques for efficient and timely execution on their computational infrastructure.			
Title: Warfighter Analytics using Smartphones for Health (WASH) ***Description:*** The Warfighter Analytics using Smartphones for Health (WASH) program will pioneer 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 explore extending these smartphone biometrics to provide the capability 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 will be closely coordinated with the Naval Health Research Center and the Armed Forces Health Surveillance Branch. ***FY 2018 Plans:*** - Propose, develop, and implement a privacy framework and privacy processes for smartphone-based physiological health and cognitive state assessment. - Design and initiate development of secure cloud-based data ingest and storage technologies for collecting, organizing, and associating user smartphone, physiological health, and behavioral data. - Propose, explore, and initiate evaluation of empirical and machine learning-based techniques for using smartphone sensor data to assess warfighter physiological health and cognitive state.	-	-	15.000
Title: Quantitative Crisis Response (QCR) ***Description:*** The Quantitative Crisis Response (QCR) program is developing digital tools that can 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 anticipated tools will be able 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. ***FY 2016 Accomplishments:*** - Refined algorithms for content discovery, deep crawling, information extraction, and information relevance to support search, analysis and visualization of collected information. - Developed dynamic, interactive, and collaborative user interface capabilities to support user needs. - Transitioned initial QCR tools to operators for assessment and feedback. ***FY 2017 Plans:***	20.929	13.750	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Evaluate semi-automated methods for web content analysis and visualization. - Integrate algorithms, analytic models, processes and methods into operational prototypes. - Conduct system evaluation with operational partners, refine prototype tools, and add advanced functionality in response to operator feedback. - Effect transitions to U.S. government agencies and Combatant Commands.			
Title: XDATA ***Description:*** The XDATA program is developing 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 include; 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 has 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 also accommodates changing problem spaces and collaborative environments. ***FY 2016 Accomplishments:*** - Developed methods and software for interactive, iterative, distributed analysis of diverse data enabling transition, integration and implementation on heterogeneous platforms. - Developed new analytics for distributed data and systems through machine learning and algorithmically scalable methods. - Developed a scalable, robust framework for user-defined, adaptable visualizations. - Developed, tested and benchmarked a library of user interfaces that provide a consistent user experience independent of scale or processor heterogeneity. - Developed integrated applications from components and interface libraries demonstrating flexible adaptation to emergent user requirements and ad-hoc tasking. ***FY 2017 Plans:*** - Optimize software components and integrated applications to allow seamless integration into a user enterprise or mission environment. - Transition end-to-end systems, components, platforms and operating environments to identified user communities.	24.457	10.629	-
Accomplishments/Planned Programs Subtotals	128.461	148.596	150.179

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

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-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	193.471	220.456	224.440	-	224.440	232.700	234.871	242.097	245.928	-	-
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	117.132	121.703	112.050	-	112.050	120.957	121.928	125.928	125.928	-	-
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	76.339	98.753	112.390	-	112.390	111.743	112.943	116.169	120.000	-	-

A. Mission Description and Budget Item Justification

This 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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	206.115	220.456	233.910	-	233.910
Current President's Budget	193.471	220.456	224.440	-	224.440
Total Adjustments	-12.644	0.000	-9.470	-	-9.470
• 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	-6.080	0.000			
• SBIR/STTR Transfer	-6.564	0.000			
• TotalOtherAdjustments	-	-	-9.470	-	-9.470

Change Summary Explanation

FY 2016: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2017: N/A

FY 2018: Decrease reflects drawdown of several Materials Processing Technology programs.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	117.132	121.703	112.050	-	112.050	120.957	121.928	125.928	125.928	-	-

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 2016	FY 2017	FY 2018
Title: Materials Processing and Manufacturing	27.602	30.621	25.816

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. This thrust is an aggregation of programs previously contained in Multifunctional Materials and Structures.

FY 2016 Accomplishments:
- Completed design of experiments-optimized model for the probabilistic process model.
- Demonstrated predictive capability of the probabilistic process model.
- Completed optimized phenomenological yield strength model for electron beam additive manufacturing (EBAM).
- Completed neural network and genetic numerical analysis for EBAM process.
- Identified candidate reinforced matrix compounds for enabling multiple platforms to be manufactured from a single tailorable feedstock material.
- Identified reconfigurable forming technologies for the rapid, cost-effective manufacture of complex shapes from matrix compounds reinforced with short, aligned elements.

FY 2017 Plans:

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Complete verification and validation of probabilistic processing model suite. - Validate phenomenological model framework. - Demonstrate rapid qualification capability on demonstration components. - Develop an aligned and tailorable planar material feedstock that meets or exceeds state-of-the-art aerospace materials performance. - Develop a reconfigurable forming method that maintains alignment and distribution in short-element reinforced matrix compounds when formed into complex shapes for DoD parts. - Initiate creation of a cost model that assesses cost competitiveness and rate insensitivity of the new material format and forming process. - Establish process limits of forming capabilities. ***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 pilot-scale production of tailorable, high-performance carbon fiber-based feedstock that meets or exceeds state-of-the-art aerospace materials capability. - Demonstrate a reconfigurable forming method at production rate for short element reinforced matrix compounds that meets or exceeds current DoD performance. - 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 functional component.			
Title: Chemical Processing for Force Protection* ***Description:*** *Formerly Materials for Force Protection 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	24.431	28.604	24.234

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
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 2016 Accomplishments:*** - Validated chemical remediation approaches against a series of DoD-relevant model compounds. - Demonstrated feasibility for achieving an efficiency of chemical agent remediation/conversion of >99%. - Expanded computational methods for reaction pathway design of structurally simple active pharmaceutical ingredients (APIs) such as ibuprofen and atropine. - Demonstrated continuous synthesis of APIs such as nevirapine and hydroxychloroquine. ***FY 2017 Plans:*** - Validate in-line analytical monitoring of newly developed chemical remediation approaches. - Increase chemical remediation/conversion of DoD-relevant model compounds to 99.9%. - Initiate designs for extension of small-scale, continuous flow molecular syntheses to metric ton/year equivalent. - Demonstrate the automated route design and continuous flow synthesis of one challenge molecule identified by DARPA. ***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 API (with stereochemistry) such as naproxen or pregabalin. - Integrate the automated route design with the continuous flow system to yield a fully automated synthesis of a DARPA-defined challenge molecule.			
Title: Functional Materials and Devices	27.704	30.597	24.320
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. This thrust is an aggregation of programs previously contained in Compact Neutron Sources. ***FY 2016 Accomplishments:***			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Initiated the development of an open source model architecture and platform applicable for multiple transductional material domains (e.g., thermoelectric, magnetoelectric and multiferroic). - Continued the identification of canonical DoD relevant system specifications that will provide performance requirements for transductional material development efforts. - Began development of a multi-physics transductional material modeling capability that incorporates interface modeling and phonon engineering. - Designed, fabricated and characterized thermoelectric materials and devices with improved performance metrics over the state-of-the-art. - Designed, fabricated and characterized materials and devices based on multiferroic or phase change materials with improved performance metrics over the state-of-the-art. - Incorporated technical findings from component design and development into expected performance metrics for integrated accelerators. - Refined components and began integration into demonstration neutron source testbed. - Used component performance tests for design tool validation and development. ***FY 2017 Plans:*** - Finalize development of multi-physics transductional material modeling capability that incorporates interface modeling and phonon engineering. - Deliver proof of concept thermoelectric devices with improved performance over the state-of-the-art. - Deliver proof of concept devices based on multiferroic or phase change materials with improved performance over the state-of-the-art. - Identify successful compact neutron source components and integrate them into prototype systems. - Perform initial integrated compact neutron source prototype testing. ***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.			
Title: Reconfigurable Systems* ***Description:*** *Formerly Reconfigurable Structures	17.613	24.141	19.980

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
In the Reconfigurable Systems thrust, new approaches are being developed to enable more rapid and robust adaptation of military 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 systems and systems-of-systems are designed for real-time resilient response to dynamic, unexpected contingencies. Research is ongoing to develop a more unified view of system behavior that allows better understanding and exploitation of complex interactions among system components, including development of a formal mathematical approach 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 2016 Accomplishments:*** - Determined limits for GPS-free navigation for short duration missions. - Modeled and developed behavioral controls to enable an Intelligence Surveillance and Reconnaissance (ISR) mission in a moderate-clutter environment. - Evaluated performance of small integrated autonomous aircraft systems in simulated warehouse environment. - Exploited novel mathematical tools and techniques for understanding the fundamentals of design science and design phenomena in complex systems and systems-of-systems. ***FY 2017 Plans:*** - Demonstrate high speed (>10 meters per second (m/s)) GPS-free flight in low clutter environment. - Demonstrate fully autonomous GPS-free flight in unknown environment. - Develop novel representations and behaviors that enable an ISR mission in a high-clutter environment. - Establish new paradigms for how systems-of-systems and their constituent parts are represented, manipulated, integrated and optimized. - Demonstrate management of complexity to enable dynamic design and composition of system-of-systems and their capabilities. - Demonstrate utility of new mathematical and algorithmic methods for system-of-systems design challenges. ***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 real-world data.			
Title: Accelerating Discovery and Innovation	3.680	7.740	17.700

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
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 an outgrowth from Multifunctional Materials and Structures that 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 understand how seemingly benign commercially available technologies may be converted or combined into threats to military operations, equipment or personnel. This program has basic research efforts funded in PE 0601101E, Project MS-01. This thrust is an aggregation of programs previously contained in Multifunction Materials and Structures. ***FY 2016 Accomplishments:*** - Engaged a broad range of technical specialists to assess and catalog threats to military operations posed by commercially available products and systems. ***FY 2017 Plans:*** - Build prototypes of commercially available threats and complete detailed assessments. - Develop methods to rapidly explore potential applications of newly discovered or newly developed science and technology data. - Develop computational methods to automate analysis of scientific and engineering data which improve its accessibility and enable new discoveries. - Execute pilot projects to analyze data collected in current DARPA programs and test the automated analysis methods. ***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. - Test software components for data ingest and discovery across multiple DARPA programs.			
Title: Multifunctional Materials and Structures	13.037	-	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
Description: The Multifunctional Materials and Structures thrust developed new methods for synthesis of high value materials, as well as compressing the timeline for integration of new materials into DoD structures, parts and systems. Research in this thrust included development of new methods for scalable, low-temperature growth of thin films for applications such as microelectronics and wear resistance. In addition, this thrust explored new approaches to compress applied materials development and integration into military platforms by at least 75% based on development of a design intent methodology that closely couples materials development with part or platform performance needs. Examples of DoD applications that benefited from this thrust include advanced electronics, lower weight and higher performance aircraft, erosion-resistant rotor blades and high-temperature materials for operation in hypersonic environments. ***FY 2016 Accomplishments:*** - Delivered thin film and coating materials with technical summaries to transition partners, Army Research Office and the Naval Research Laboratory. - Demonstrated initial integrated material, process, design and manufacturing tool demonstrations for hypersonic hot structure aeroshell. - Created material system development and designed framework and linked material informatics results to identify aeroshell mission performance drivers. - Generated a sub-component design concept and a sub-element design for hypersonic hot structure aeroshell. - Established an independent test and evaluation capability for hypersonic hot structure aeroshell.			
Title: Manufacturable Gradient Index Optics (M-GRIN)	3.065	-	-
Description: The Manufacturable Gradient Index Optics (M-GRIN) program sought to advance the development of gradient index optics (GRIN) lenses from a Technology Readiness Level (TRL) 3 to a Manufacturing Readiness Level (MRL) 6. The program expanded the application of GRIN by providing compact, lightweight, and cost-effective optical systems with controlled dispersion and aberrations that will replace large assemblies of conventional lenses. The ability to create entirely new optical materials and surfaces created the potential for new or significantly improved military optical applications, such as solar concentrators, portable designators, highly efficient fiber optics and imaging systems. The program also sought to extend GRIN manufacturing technologies to glass, ceramic and other inorganic materials to allow for small, lightweight, customized optical elements for mid-wave and long-wave infrared (MWIR and LWIR) applications. A key component of the program was to develop new design tools that enabled optics designers to incorporate dynamic material properties, fabrication methods and manufacturing tolerances. The integration of new materials, design tools and manufacturing processes enabled previously unattainable 3-D optical designs to be manufactured. ***FY 2016 Accomplishments:***			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Completed prototype builds to demonstrate system performance and/or size, weight and power (SWaP) improvement from GRIN optical systems. - Completed thermal models and implemented them in optical system designs to mitigate thermal effects on optical performance. - Completed demonstration of rapid redevelopment/prototyping capability.			
Accomplishments/Planned Programs Subtotals	117.132	121.703	112.050

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	76.339	98.753	112.390	-	112.390	111.743	112.943	116.169	120.000	-	-

A. Mission Description and Budget Item Justification

This 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: BioDesign	14.435	15.265	12.962

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 2016 Accomplishments:
- Demonstrated the ability to localize relevant molecules and events to one or more intracellular compartment(s) (e.g., membrane, nucleus, or cytoplasm) upon the application of a challenge compound.
- Demonstrated the ability to identify intracellular components and events that occur within minutes after the application of a challenge compound.
- Reconstructed and confirmed greater than 60 percent of the molecules and mechanistic events that comprise the canonical mechanism of action for a demonstration compound which has been applied to cells.

FY 2017 Plans:
- Continue to demonstrate the ability to localize relevant molecules and events to one or more intracellular compartment(s) (e.g., membrane, nucleus, or cytoplasm) upon the application of a challenge compound.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate the ability to identify intracellular components and events that occur within seconds after the application of a challenge compound. - Reconstruct and confirm greater than 80 percent of the molecules and mechanistic events that comprise the canonical mechanism of action for a demonstration compound which has been applied to cells. ***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. - 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.			
Title: Living Foundries	27.945	23.712	21.020
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 2016 Accomplishments:*** - Demonstrated the ability of infrastructure pipelines to rapidly generate target molecules.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Initiated pressure tests of the foundries to test capabilities of the design and prototyping pipelines in demonstrating the speed, breadth, and efficacy of the infrastructure designs. - Implemented learn capabilities into design algorithms based on testing and characterization of previously prototyped targets in order to improve the processes. - Improved forward design and rapid optimization of target molecules via the prototyping facility's established processes. - Initiated development of computational infrastructure to link component technologies and enable end-to-end process monitoring. ***FY 2017 Plans:*** - Further advance infrastructure pipelines capable of rapidly prototyping and generating DoD-relevant molecules, with significant emphasis on system integration, throughput, and process optimization. - Continue pressure tests of the infrastructure facilities to test capabilities of the design and prototyping pipelines in demonstrating the speed, breadth, and efficacy of the infrastructure designs. - Test the ability to produce ten molecules that are relevant to the DoD. - Incorporate learn capabilities into design algorithms based on testing and characterization of previously prototyped targets in order to improve the processes. - Begin developing the infrastructure pipelines to prototype production of molecules. ***FY 2018 Plans:*** - 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 prototyping strains that produce molecules. - Characterize impact of machine learning capabilities on design algorithms and identify increases in prototyping process efficiency.			
Title: Adaptive Immunomodulation-Based Therapeutics	23.435	24.654	16.962
Description: The Adaptive Immunomodulation-Based Therapeutics program will develop platform technologies to interrogate and define the biological pathways that modulate the immune response and critical organ function. 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 map the bioelectric code. This program will also identify immune function correlates for health and early detection of disease. An additional approach involves characterizing the host response in patients with severe infections, and developing a quantitative framework that can be used to guide modulation of the immune response. Algorithms will be developed to evaluate and predict various physiological conditions within an individual. Advances made under the Adaptive Immunomodulation-Based Therapeutics program will improve our response capability against severe infectious diseases and biological threats and offer new avenues for treating disease or organ function.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
FY 2016 Accomplishments: - Developed novel interface technologies to monitor and stimulate peripheral nerves to selectively alter organ function. - Compared specificity of novel interface technologies with state of the art whole-nerve stimulation devices. - Initiated development of input/output models of mammalian autonomic functions such as the immune system and/or the autonomic stress response. - Identified peripheral intervention points and modulation parameters for control of mammalian autonomic function for improving health or treating disease. - Developed multi-site electrode array and stimulator to improve targeting of vagal nerve stimulation. ***FY 2017 Plans:*** - Initiate demonstrations of advanced peripheral nerve interface technologies in small and large animal models to improve inflammatory and neuropsychiatric disease outcomes. - Develop computational models to simulate noninvasive peripheral nerve modulation approaches for desired physiological outcome. - Elucidate mechanisms of action for peripheral nerve modulation via noninvasive techniques. - Identify panels of relevant biomarkers that are indicative of diseased state and provide a reliable and specific surrogate measure to track physiological response to peripheral nerve modulation. ***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. - Conduct in vivo safety and efficacy studies to evaluate long-term bio-interface functionality.			
Title: Biological Robustness in Complex Settings (BRICS)	10.524	12.521	10.962
Description: The Biological Robustness in Complex Settings (BRICS) program will leverage newly developed technologies to enable radical new approaches for gene editing and engineering biology. This area will focus on the creation of enabling technologies that will facilitate the development and integration of fundamental tools and methods being explored under the BRICS program. Research within this area may focus on the development of tools for safe genetic engineering of new species, such as plants, as well as traditionally intractable species, and tools for high-resolution characterization of biological communities. Ultimately, this area seeks to integrate the fundamental component technologies developed under PE 0601101E, TRS-01 into a platform technology capable of engineering robust, stable, and safe communities for the prevention and treatment of disease.			
FY 2016 Accomplishments:			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Developed technologies to design and build biological pathways that will function in undomesticated microbial species from a wide range of phyla (prokaryotic or eukaryotic). - Developed theoretical tools that allow the prediction of metrics of behavior and community dynamics, such as species composition, resource utilization, and small molecule communication within a multi-species consortium. - Fabricated generalizable culture substrates that provide control over community structure and composition and support the growth of both prokaryotic and eukaryotic cells. - Investigated novel strategies for temporal and spatial control of gene editing. ***FY 2017 Plans:*** - Identify promising component technologies that may be readily adapted into a platform for engineering robust, stable, and safe biological communities. - Demonstrate reliable function of engineered microbial communities in laboratory environments. - Demonstrate potential for safe use of engineered consortia under conditions relevant to specific applications. ***FY 2018 Plans:*** - Integrate promising component technologies to engineer a functional microbial community. - Test the robustness, stability, and safety of newly engineered microbial communities. - Evaluate limits for engineered microbial communities.			
Title: Enhancing Neuroplasticity	-	15.601	19.430
Description: The Enhancing Neuroplasticity program will explore and develop stimulation methods and non-invasive devices to promote synaptic plasticity that is expected to impact higher cognitive functions. 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. Once successfully identified, the underlying mechanisms of targeted plasticity training can be applied to a broad range of cognitive skill training within the Department of Defense, including foreign language learning, or data and intelligence analysis. ***FY 2017 Plans:*** - Determine the effects of peripheral nerve stimulation parameters on brain regions that modulate plasticity. - Compare effectiveness of nerve stimulation sites in promoting synaptic plasticity and improving performance on cognitive skill learning tasks. - Demonstrate effects of training on neurons in task-specific sensory and/or motor areas of the brain. - Initiate studies to compare efficacy of invasive and noninvasive stimulators. ***FY 2018 Plans:*** - Demonstrate effects of training on neurons and neuronal network connectivity in task-specific areas of the brain.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Evaluate the acute effects 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.			
Title: Biosecurity for Biotechnology ***Description:*** The Biosecurity for Biotechnology program will develop new biological tools to contain, control, and reverse the activities of engineered genes. 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 explore new tools to recall or reverse engineered changes. The Biosecurity for Biotechnology program builds upon technologies investigated in the Biological Robustness in Complex Settings program. ***FY 2017 Plans:*** - Investigate novel gene editing controller mechanisms and failure modes. ***FY 2018 Plans:*** - Investigate novel small molecule and genetic countermeasures to prevent genome 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.	-	3.750	11.844
Title: Accelerated Agricultural Engineering ***Description:*** Changes in the environment including drought, salt-water intrusion, and acute or chronic flooding, as well as introductions of invasive pests and pathogens, present a significant risk to agricultural production. Conventional methods, such as plant breeding, are generally slow and ineffective against such changes. Research within this program will investigate novel methods for transmission of genetic materials and the controlled integration of selected genetic elements into plant genomes. The goal is to develop technologies that can reduce the timeline for agricultural countermeasure development and dissemination, and increase agricultural stability and resilience against evolving environmental changes and pathogens. The Accelerated Agricultural Engineering program builds upon technologies investigated in the Biological Robustness in Complex Settings program. ***FY 2017 Plans:*** - Investigate novel approaches for delivery of gene editing technology to multiple plant tissues. ***FY 2018 Plans:*** - Develop a flexible plant transformation platform to genetically modify plants.	-	3.250	10.700

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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.			
Title: Engineering Function ***Description:*** The Engineering Function program will leverage advances in synthetic biology and bioengineering to enhance the natural capabilities of biological systems. To date, imparted functionality in engineered living systems has been limited by the vast biological complexity of the system and lack of understanding of the relationship between the living system and its local environment. This program will include research to develop discovery and automation tools as well as synthesis techniques that expand upon the toolbox of genetically encoded constructs and biologic structures for engineered living systems. This program will enable the design of engineered living systems, expanding approaches for multi-cellular system engineering for natural and extreme environments, higher levels of complexity and system-of-system designs, and self-assembled manufacturing. ***FY 2018 Plans:*** - Assess the feasibility of intracellular and intercellular engineering to enhance cellular function. - Investigate methods for effectively assessing the compatibility of newly engineered functionalities in biological systems across multiple size scales and in multiple environments. - Begin development of new automation technologies with the ability to engineer complex biological systems and integrate self-assembled manufacturing.	-	-	8.510
Accomplishments/Planned Programs Subtotals	76.339	98.753	112.390

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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COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	168.233	221.911	295.447	-	295.447	234.685	192.923	219.473	223.973	-	-
ELT-01: *ELECTRONICS TECHNOLOGY*	-	168.233	221.911	295.447	-	295.447	234.685	192.923	219.473	223.973	-	-

A. Mission Description and Budget Item Justification

This 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 Electronics 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.

This project also 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. Beyond Scaling programs within the Electronics Technology project will look at reducing barriers to making specialized circuits in today's silicon hardware. These programs 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.

The 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.

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B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	174.798	221.911	234.424	-	234.424
Current President's Budget	168.233	221.911	295.447	-	295.447
Total Adjustments	-6.565	0.000	61.023	-	61.023
• 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	-0.999	0.000			
• SBIR/STTR Transfer	-5.566	0.000			
• TotalOtherAdjustments	-	-	61.023	-	61.023

Change Summary Explanation

FY 2016: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2017: N/A

FY 2018: Increase reflects Beyond Scaling - Materials and Architectures and Design programs, which focus on reducing barriers in making specialized circuits.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Common Heterogeneous integration & IP reuse Strategies (CHIPS)	8.000	28.500	28.000

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, silicon technologies, and compound semiconductor (CS) materials. Although integrating CS and silicon has been shown to increase the performance of radio frequency devices, integration is both costly and time consuming. CHIPS will therefore pursue standardized interfaces for integrating a variety of intellectual property (IP) blocks, including for CS and silicon materials, 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 2016 Accomplishments:

- Investigated technology choices for analog and digital technologies and the best methods of integration in order to achieve program objectives.
- Identified partners for fabrication and integration.
- Evaluated technology for various analog functional blocks for optimal use of mixed technologies.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Investigated tradeoffs for various integration strategies for analog and digital technologies, focusing on performance, form factor, and cost. - Developed a cost model to analyze the impact of IP re-use using insight gained from large defense contractor development cycle study. - Studied the system level impact of IP re-use for the optimal use of radio frequency (RF) mixed technology functional blocks. ***FY 2017 Plans:*** - Finalize standards for high-bandwidth interfaces of digital and analog chiplet-based interconnections. - Study the system level impact of IP re-use for the optimal use of digital and analog functional blocks. - Initiate heterogeneous circuit demonstrations to verify interface standards for chiplet-based integration of digital and analog IP blocks, including commercial and DoD blocks. - Initiate module design activities to determine performance and program benefits of new processes enabled by the program. ***FY 2018 Plans:*** - Complete heterogeneous circuit demonstrations to verify interface standards for chiplet-based integration of digital and analog IP blocks, including commercial and DoD blocks. - 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.			
Title: Direct On-Chip Digital Optical Synthesis (DODOS)	9.000	13.000	13.000
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 2016 Accomplishments:			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Validated device-level performance requirements, such as the control-loop bandwidths and optical link budget, needed to reach the DODOS program metrics at the system level. - Prototyped critical photonic components in processes consistent with subsequent co-integration. - Demonstrated tabletop DODOS system, utilizing microscale components. ***FY 2017 Plans:*** - Validate prototype photonic integrated circuits containing all optical components required by the DODOS system architecture. - Implement off-chip electronics and algorithms and demonstrate DODOS electro-optic functionality. - Develop packaging techniques to co-integrate DODOS photonics and electronic control circuits. ***FY 2018 Plans:*** - Demonstrate and deliver DODOS prototypes with co-integrated photonic and electronic components meeting the performance metrics. - Complete proof-of-concept lab demonstrations of DoD-relevant applications employing DODOS technology.			
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 2016 Accomplishments:*** - Demonstrated a highly digital common hardware module serving up to 32 elements of a phased array. - Demonstrated software configuration of the common module radio frequency performance (e.g. frequency, bandwidth, waveform) to meet the needs of a wide range of DoD radar, electronic warfare, signals intelligence, and communications applications. - Demonstrated radio frequency (RF) beam steering in a near field antenna range using the ACT highly digital common module interfaced to a 1x16 element C-band antenna.	25.551	20.000	10.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrated an antenna element with > 100 reconfiguration switches that can tune center frequency from 6-12 GHz, polarization and steer RF beams and beam nulls. - Developed a plan and preliminary designs to migrate the common module to the 14 nm Global Foundries process node where a nearly 50% reduction in power consumption is expected. ***FY 2017 Plans:*** - Demonstrate common module hardware viability through government testing in three different government furnished phased array demonstrations. - Develop the ACT common module using an advanced 14 nm process node and demonstrate the performance improvement compared to the common module developed with an earlier 32 nm node in Phase 1. - Demonstrate rapid technology refresh of the common modules developed in Phase 1. - Drive the ACT common module technology transition process by gathering and sharing test results with potential users. - Develop a reconfigurable 16 element antenna array that can tune center frequency and polarization. ***FY 2018 Plans:*** - Demonstrate arbitrary control of the surface current in a 16 element antenna array. - Demonstrate five or more common modules interfaced together to form a phased array with greater than 100 elements.			
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC)	12.000	18.000	18.000
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 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 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 2016 Accomplishments:*** - Initiated the design and modeling of a wide-bandwidth, high power mm-wave vacuum electronic amplifier.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Identified performance parameters and engineering tradeoffs required to meet or exceed the program metrics for both power and bandwidth in a compact form factor, incorporating new concepts for novel beam-wave interaction structures and advanced thermal management. ***FY 2017 Plans:*** - Assess state of the art in cathodes, vacuum windows, and magnetic structures for electron beam transport and identify components and technologies that meet or exceed design requirements. - Design, fabricate, and test high current-density cathodes capable of producing beam current consistent with amplifier output power requirements. - Design, fabricate, and test wide bandwidth interaction structures with high beam-wave interaction efficiency and high power handling capability. ***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.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM)	10.000	21.911	20.500
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 2016 Accomplishments:***			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Developed preliminary models and designed architectures for chip-scale, waveguide optical gyroscopes, which combine the essential components and functionality of ring-laser gyroscopes into a photonic integrated circuit. - Developed preliminary models for optically interrogated MEMS inertial sensors, leveraging the high sensitivity of optical interrogation with precision machining and low-cost, size, weight, and power (SWaP) enabled by MEMS. ***FY 2017 Plans:*** - Develop processes for co-fabrication of MEMS and photonic integrated circuits. - Design and simulate photonic and MEMS-photonic sensors suitable for high shock survival. - Integrate component technology and demonstrate integrated photonic-MEMS inertial sensors with beyond navigation grade performance. ***FY 2018 Plans:*** - Design and fabricate heterogeneously integrated, chip-scale waveguide optical gyroscopes. - Demonstrate navigation grade accuracy and stability of integrated inertial sensors.			
Title: Near Zero Energy RF and Sensor Operations (N-ZERO)	4.500	15.000	20.000
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 2016 Accomplishments:*** - Designed and fabricated hardware components and microsystems for detecting RF signals with received power levels less than 1 nano-Watt while consuming less than 10 nW of power. - Designed and fabricated hardware components and microsystems for detecting and discriminating the presence of a specific machine at a distance of less than 0.5 m while consuming less than 10 nW of power consumption. - Identified government application spaces and transition paths that will make use of N-ZERO detection and signal processing. ***FY 2017 Plans:***			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Evaluate the detection performance and power consumption of the RF and physical sensor microsystems. - Perform data collection measurements for the purpose of designing and evaluating the performance of N-ZERO devices and microsystems in higher noise, DoD relevant environments. - Design, fabricate and evaluate microsystems enabling passive or near zero energy collection, processing and detection of RF communications and physical sensor signatures at reduced (10 fold from the original specifications) signal strength. ***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 (100 fold from 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.			
Title: Wafer-scale Infrared Detectors (WIRED) ***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 2016 Accomplishments:*** - Explored the fundamental properties of disordered materials, and investigated the processes that affect sensor performance at elevated operating temperatures. - Investigated MWIR sensor technology for compatibility with wafer-scale processing and high performance at operating temperatures suitable with low-cost thermoelectric coolers. - Investigated SWIR sensor technology for compatibility with wafer-scale processing and scalability to a near diffraction-limited pixel pitch. ***FY 2017 Plans:*** - Develop models that describe the fundamental behavior of disordered materials and apply them to device-level simulations.	10.000	14.000	18.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate imaging from MWIR detectors that are integrated directly onto readout integrated circuits (ROICs) and evaluate detector performance/characteristics at temperatures of 230 K. - Demonstrate imaging from small pixel SWIR detectors that are integrated directly onto ROICs and evaluate detector performance/characteristics. ***FY 2018 Plans:*** - Demonstrate imaging from MWIR detectors that are integrated directly onto 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. - Develop materials and device physics models to design LWIR devices. - Demonstrate performance of a LWIR device at temperatures of 298 K.			
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 aims to 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 2016 Accomplishments:*** - Designed and simulated non-mechanically steered millimeter-scale transmit and receive unit cells with 5mW of output power. - Performed preliminary thermal modeling of the device, demonstrating a path to air-cooling. ***FY 2017 Plans:*** - Complete architecture design and application study for chip-scale LIDAR. - Fabricate and test a millimeter-scale unit cell transmit and receive elements. ***FY 2018 Plans:*** - Simulate low-loss grating design. - Demonstrate a scalable optical tile with integrated amplification.	12.000	16.911	22.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Complete preliminary LIDAR system designs.			
Title: Circuit Realization At Faster Timescales (CRAFT)	15.000	26.000	20.000

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 2016 Accomplishments:
- Completed design submissions for the first Fin Field Effect Transistor (FinFET) multi-project wafer shuttle run for technology evaluation.
- Completed initial definition of the design flow for the object oriented design methodology.
- Established a repository where the intellectual property (IP), methodology, and tools required to implement the object oriented design flow will be stored and distributed.

FY 2017 Plans:
- Complete the first two FinFET multi-project wafer shuttle runs.
- Evaluate designs from first FinFET multi-project wafer shuttle run.
- Initiate efforts to transfer design elements between foundries and across technology nodes.
- Complete initial testing of at least two full object oriented design flows.
- Start design and intellectual property transfer to the repository for storage and distribution.
- Implement and examine the effectiveness of existing, commercially-available IP obfuscation techniques on a DoD-relevant chip.

FY 2018 Plans:
- Complete the third FinFET multi-project wafer shuttle run with design fabrication done at multiple foundries and at multiple technology nodes.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Evaluate designs from the second and third multi-project wafer shuttle runs. - Utilize design flow and IP from the CRAFT repository to complete the DoD reference design. - 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.			
Title: Atomic Clock with Enhanced Stability (ACES)	3.127	10.589	21.000
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 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 2016 Accomplishments:*** - Developed preliminary block diagrams, component specifications, and physics models for candidate ACES architectures. ***FY 2017 Plans:*** - Develop component specifications and schematics to support ACES devices. - Fabricate and test prototype component technology for ACES devices. - Perform physics simulations and modelling to establish predicted compliance of ACES clock architectures with ACES program objectives. ***FY 2018 Plans:*** - Perform laboratory demonstration of functioning ACES clock meeting Phase 1 metrics of power consumption, retrace, and instability. - Design integrated physics package meeting Phase 2 size, weight, and power (SWaP) objectives. - Fabricate and test an integrated physics package meeting the ACES Phase 2 SWaP, retrace, and aging goals.			
Title: Limits of Thermal Sensors (LOTS)	-	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 could			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 response times, and uncooled detectors called microbolometers, which offer significant SWaP-C reductions. LOTS seeks to develop microbolometers that can compete with larger detectors in terms of sensitivity required to detect signals over long ranges and response time to avoid image blur. These technologies should 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 2017 Plans:*** - Investigate preliminary architecture and design parameters to achieve sensitive microbolometer performance. - Demonstrate performance improvement in uncooled microbolometers over current production devices. - Demonstrate sensor fabrication in a production environment. ***FY 2018 Plans:*** - Build LWIR cameras with refined focal-plane array and calibrate for operation over -40 C to 65 C temperature range. - Test cameras for radiometric performance and sensitivity and deliver camera hardware.			
Title: Atomic Magnetometry for Biological Imaging In Earth's Native Terrain (AMBIIENT)	-	-	9.247
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 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, preferably using the sensing mechanism to do this subtraction. 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.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Perform laboratory validation of proof-of-principle of gradient sensor physics performance.			
Title: Dynamic Range-enhanced Electronics and Materials (DREaM) ***Description:*** The Dynamic Range-enhanced Electronics and Materials (DREaM) program will develop intrinsically linear 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. By contrast, existing RF transistor technologies amplify RF signals but produce undesired interference in the RF spectrum due to their poor linearity. Traditional RF transistor design typically requires a trade-off between high linearity and broadcast range. DREAM will overcome this tradeoff by employing new ultra-wide band gap and high carrier mobility materials in novel transistor-level designs and highly-scaled transistor structures. The resulting device technology should allow future RF electronics to increase their operating range without polluting the already-congested RF spectrum 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. - Develop high power and linear power transistor prototype that provide three times more power density and linearity than the state of the art. - Develop low noise and lower power linear transistor prototype that provide 10 times improvement of linearity figure of merit than the state of the art.	-	-	14.000
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-	-	-	9.000

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 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 and begin initial circuit design for high efficiency receivers. - Determine best choices for transmitter technology based on initial simulations of beam transmission through mission-relevant atmospheric conditions.			
Title: Intelligent Design of Electronic Artifacts (IDEA) ***Description:*** The Intelligent Design of Electronic Artifacts (IDEA) program aims to develop intelligent, free, and open-source development tools and building blocks to provide custom integrated circuits (IC) for mission critical DoD systems. Currently, leading-edge IC development requires large teams of domain experts and costs up to $100M per IC design. These hurdles limit DoD s ability to rapidly access high-performance electronic components and encourage the use of sub-optimal or insecure alternatives. IDEA would reduce the cost and expertise barriers to IC design by leveraging 50 years of chip design knowledge, ongoing advances in machine intelligence, and the incredible growth in public, cloud-based computational resources. The program would develop evolvable, open-source IC design tools and IC building block libraries that can be stored in publicly available cloud infrastructure. This would enable small teams of system and algorithm experts without chip design experience to develop custom ICs at a very low cost and quickly implement these designs in hardware. IDEA would therefore facilitate the development of critical, custom components for the vast majority of DoD missions, including for imaging, communication, electronic warfare, radar, and security applications. ***FY 2018 Plans:*** - Demonstrate the use of open source tool Verilog to chip compiler and a library of open source digital building blocks to create a viable application specific circuit. - Demonstrate technology independent generation of physical standard cell, IO, and memory libraries using a set of open source tools. - Develop preliminary methods and algorithms for integrating intelligence/learning into the development tools - Develop methods and algorithms that make chip development tools performance scalable across publicly available cloud infrastructure.	-	-	9.700
Title: Beyond Scaling - Materials	-	-	19.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 vertical integration using modern and older technology nodes. - Demonstrate the ability to store the results of computer processing in close proximity to computer logic blocks.			
Title: Beyond Scaling - Architectures and Designs	-	-	35.000
Description: The Beyond Scaling - Devices and Architectures 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. Previous DARPA and commercial programs on tightly integrated heterogeneous systems, high-speed simulation software, and open-source hardware development provide confidence in this approach. 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:*** - Execute machine generation of physical objects to demonstrate a reduction in circuit design time.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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.			
Title: Adaptive Radio Frequency Technology (ART) ***Description:*** The Adaptive Radio Frequency Technology (ART) program will develop a technology base to enable real-time-adaptable radios for individual warfighters and small unmanned systems. ART technologies would provide capabilities for next-generation communications, sensing, and electronic warfare, including reconfigurable radios and efficient and compact signal identification capabilities. Goals of the ART program include (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 requirements; and (3) significantly reducing the size, weight, and power (SWaP) of such radios. ART will enable the use of a single design pathway for multiple, unique radio frequency (RF) systems, thus dramatically reducing military procurement and sustainment costs. ART will also advance the hardware and software used in radio frequency (RF) systems by developing a flexible, reconfigurable architecture that can adapt to various RF waveforms. ***FY 2016 Accomplishments:*** - Investigated transition paths for phase change switch technology including potential transitions into a commercial semiconductor foundry. - Developed transition paths for Radio-Frequency Field-Programmable Gate Arrays reconfigurable RF front-ends including the supplying of demo units to DoD end users and the investigation of commercialization paths for supplying the technology to the DoD. - Increased power handling of phase change switch technology to > 0.6W and improved the reliability to > 0.5 million cycles to meet the performance requirements of military and commercial communications systems. ***FY 2017 Plans:*** - Demonstrate an RF front-end reconfigurable between five different RF systems with performance approaching (> 90%) that of a fixed point solution. - Finalize transition plans for a fully reconfigurable RF circuit technology at the component and system levels. - Develop enhanced version of an existing RF-FPGA chip and integrate it onto a wideband reconfigurable RF system that can be used to develop and test advanced radio capabilities.	9.040	8.500	-
Title: Diverse & Accessible Heterogeneous Integration (DAHI) ***Description:*** The Diverse Accessible Heterogeneous Integration (DAHI) program is developing 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 would enable dramatic size, weight, and volume reductions and higher performance for DoD electronic warfare, communications, and radar	16.000	11.500	-

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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, builds 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 focuses on developing and demonstrating high-performance SOC for DoD-specific applications. The program should also enhance the manufacturing yield and reliability of heterogeneous integration capabilities and demonstrate innovative, advanced microsystems that leverage heterogeneous integration. Relevant manufacturing processes would be made available to a wide variety of designers from the DoD laboratories, federally funded research and development centers, academia, and industry. This program has advanced technology development efforts funded in PE 0603739E, Project MT-15. ***FY 2016 Accomplishments:*** - Demonstrated heterogeneous integration of advanced node silicon complementary metal-oxide semiconductor (CMOS) processes achieved with diverse types of compound semiconductor transistors and MEMS, including interconnect and thermal management approaches. - Transitioned multi-user foundry interface to independent design service from proprietary foundry model to enable community access to diverse heterogeneous integration processes. - Demonstrated sustainable model and accessibility via foundry/customer engagements, including detailed cost models and quotations. ***FY 2017 Plans:*** - Demonstrate heterogeneous integration process with more sophisticated circuit demonstrations using silicon interposer technology combining heterogeneously integrated multi-technology circuits with high Q passive technologies. - Demonstrate integration of emerging device technologies into established heterogeneous integration process flow with minimal process deviation.			
Title: Vanishing Programmable Resources (VAPR) ***Description:*** The Vanishing Programmable Resources (VAPR) program will create microelectronic and mechanical systems capable of physically vanishing in a controlled, triggerable manner. This advance could help avoid problems associated with unrecovered devices, including their potential use by unauthorized individuals and the compromise of intellectual property. The resulting technologies could enable 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 will develop and establish an initial set of transient materials and components along with the required manufacturing processes. The resulting systems should perform 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 will be demonstrated through two final test platforms. A	9.000	9.000	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
vanishing air delivery vehicle capable of precise, gentle drops of small payloads (~3 lbs.) seeks to demonstrate the feasibility of transient structural materials. A sensor with a wireless link seeks to demonstrate the manufacturability of transient electronics. Both demonstrations are intended to fully function on their own and to serve as a leading indicator of the potential systems and concepts-of-operation that VAPR could enable. ***FY 2016 Accomplishments:*** - Completed integration of transient devices and materials to form fully functional microsystems. - Achieved a transience time of less than or equal to 30 seconds for transient functional microsystems. - Improved the variability of transience time to less than or equal to 10 seconds. - Realized reliable operation of transient microsystems for greater than 100 hours after deployment, with subsequent controlled transience. ***FY 2017 Plans:*** - Optimize novel transient materials for application in the air delivery vehicle to meet structural requirements while guaranteeing full and complete transience. - Initiate commercial-scale production of novel transient materials. - Complete preliminary design reviews of air delivery system that meets program-defined air-release and landing specifications.			
Title: IntraChip Enhanced Cooling (ICECool)	9.750	-	-
Description: The IntraChip Enhanced Cooling (ICECool) program incorporated thermal management techniques directly into microelectronics. This enabled operation of military electronic systems at higher powers while significantly reducing their size and weight. Today, the high-power operation of military electronics is restricted by the amount of heat created. ICECool overcame these limitations by significantly increasing the rate of heat removal in microelectronics. Areas of focus included overcoming the limits of existing thermal management techniques, determining the feasibility of exploiting these techniques within a single chip or stack of chips, and ensuring the reliable operation of microelectronics that produce high levels of heat. ICECool integrated chip-level thermal management techniques into prototype, high-power electronics in radio frequency arrays and embedded computing systems. Successful program completion will meet the capability needs of next-generation military systems, enabling increased radar range, improved target tracking, and accelerated processing using high power computing. ***FY 2016 Accomplishments:*** - Completed reliability simulations of ICECool electrical demonstration modules to establish mean time to failure and compatibility with relevant military specifications. - Demonstrated minimal degradation of electrical demonstration vehicles under 100 hour life tests and 1000 temperature cycle tests.			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Tested and demonstrated fully-functional High Power Amplifiers with a 6x increase in output power and 2-3x improvement in efficiency over the baseline GaN-on-SiC approach. - Designed application-ready ICECool modules and subarrays to facilitate transition of ICECool enabled components into relevant systems. - Engaged in transition activities for the ICECool technology to enable insertion of ICECool enabled components in relevant subsystems such as transmit/receive modules and embedded airborne computing platforms. - Demonstrated a fully functional microprocessor with embedded two phase cooling, showing a decrease in chip temperature of 25C for the same workload as an air cooled processor, providing higher reliability and performance enabled by high hot spot cooling capabilities.			
Title: In vivo Nanoplatforms (IVN)	8.265	-	-
Description: The In vivo Nanoplatforms (IVN) program developed the nanoscale systems necessary for in vivo sensing and physiologic monitoring and delivery vehicles for targeted biological therapeutics against chemical and biological (chem-bio) threat agents. The nanoscale components enabled continuous in vivo monitoring of physiological biomarkers. A reprogrammable therapeutic platform that targets gene regulatory sequences enabled tailored therapeutic delivery to specific areas of the body (e.g., cells, tissue, compartments) in response to traditional, emergent, and engineered threats. The key challenges to developing these systems included safety, toxicity, biocompatibility, sensitivity, response, and targeted delivery. The IVN program achieved diagnostic and therapeutic goals that enabled a versatile, rapidly adaptable system to provide operational support to the warfighter in any location. ***FY 2016 Accomplishments:*** - Demonstrated enhanced therapeutic performance via molecular targeting approaches in an animal model. - Demonstrated the ability of skin-based sensors to detect physiologically relevant molecules (e.g., pH, ions, glucose, lactate, and cortisol) in an animal model. - Demonstrated the ability of an in vivo nanoplatform to protect against infectious disease in an animal model. - Continued to update regulatory approval pathway with results from animal model safety and efficacy testing.			
Title: Pixel Network (PIXNET) for Dynamic Visualization	4.000	-	-
Description: The Pixel Network (PIXNET) for Dynamic Visualization program enabled individual warfighters with a compact, versatile, and affordable camera for target detection, recognition, and identification (DRI) in both daylight and no-light conditions. The camera eliminates limitations posed by current camera systems. PIXNET enabled real-time fusion of thermal and reflected infrared (IR) imagery, allowing the warfighter to better detect camouflaged targets and distinguish decoys. The program focused on significantly reducing the size, weight, and power (SWaP) of IR sensors, enabling new capabilities for small unmanned aerial vehicles, rifle sights, and vehicle-mounted, helmet-mounted, and handheld systems. In the future, PIXNET capabilities will also			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
enable real-time wireless sharing of video data, which may support a peer-to-peer image-sharing system for establishing a better common operating picture of the battlefield. ***FY 2016 Accomplishments:*** - Demonstrated multi-band fusion with the visible and near infrared/long-wave infrared (VNIR/LWIR) camera. - Demonstrated the short-wave infrared/long-wave infrared (SWIR/LWIR) helmet mounted camera with real-time, on-board multi-band fusion. - Demonstrated a bench-scale brassboard SWIR/MWIR camera with image fusion algorithms on an external laptop to show functionality.			
Title: Hyper-wideband Enabled RF Messaging (HERMES) ***Description:*** The Hyper-wideband Enabled RF Messaging (HERMES) program developed architectures and technologies to maintain assured radio frequency (RF) links in contested environments. Today, RF links are allocated and confined to slices of spectrum to prevent interference among users; this however facilitates enemy attempts to jam the link. HERMES explored a combination of techniques to suppress enemy jammers and guarantee communications in situations where the RF link is critical. Technology developed under the HERMES program enabled RF links to access tremendous amounts of bandwidth without jeopardizing other links. Advances under the HERMES program will prove increasingly important given the growing dependence of modern weapons systems on RF links for communications, command and control, geolocation and battle management. ***FY 2016 Accomplishments:*** - Conducted a demonstration of prototype direct-sequence spread-spectrum receiver with 6 GHz of instantaneous bandwidth and suppression of multi-path interference.	3.000	-	-
Accomplishments/Planned Programs Subtotals	168.233	221.911	295.447

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	165.764	182.327	155.406	-	155.406	162.028	176.551	181.434	180.316	-	-
AIR-01: *ADVANCED AEROSPACE SYSTEMS*	-	165.764	182.327	155.406	-	155.406	162.028	176.551	181.434	180.316	-	-

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 dramatically reduce costs associated with advanced aeronautical systems and provide revolutionary new system capabilities for satisfying current and projected military mission requirements. 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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	173.631	182.327	156.089	-	156.089
Current President's Budget	165.764	182.327	155.406	-	155.406
Total Adjustments	-7.867	0.000	-0.683	-	-0.683
• 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	-1.609	0.000			
• SBIR/STTR Transfer	-6.258	0.000			
• TotalOtherAdjustments	-	-	-0.683	-	-0.683

Change Summary Explanation

FY 2016: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2017: N/A
FY 2018: Decrease reflects minor program repricing.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Tactically Exploited Reconnaissance Node (TERN)	30.391	12.000	5.000
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			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018

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 (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 2016 Accomplishments:
- Completed high fidelity integrated ship-aircraft simulation.
- Commenced procurement of long-lead demonstrator system components.
- Performed detailed design of demonstrator aircraft.
- Began fabrication and testing of demonstrator system hardware.
- Initiated software in the loop / hardware in the loop build.
- Completed integrated testing of propulsion subsystem.
- Performed subsystem risk reduction demonstrations.

FY 2017 Plans:
- Conduct demonstrator system Critical Design Review (CDR).
- Commence demonstrator system wing and fuselage fabrication.
- Perform demonstrator system integrated avionics testing.
- Conduct integrated propulsion system testing.
- Complete vehicle structure tooling.
- Conduct vehicle structure assembly and testing.
- Conduct demonstrator system assembly.
- Initiate fabrication of second demonstrator air vehicle.

FY 2018 Plans:
- 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.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Refine demonstrator system flight control. - Conduct land-based demonstrator system flight testing. - Commence system integration checkout of second air vehicle demonstrator.			
Title: Collaborative Operations in Denied Environment (CODE)	28.543	29.027	30.106
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 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 2016 Accomplishments:*** - Began selection of algorithms for the current leading capabilities: collaborative navigation without Global Positioning System (GPS), formation flight, simultaneous time of arrival from multiple azimuths against moving targets, dynamic prioritized target re-assignment to compensate for attrition, synchronized search using multiple sensor types, collaborative communication using relays or other techniques, closed loop tracking and identification, and terse communication protocols for data fusion and task allocation. - Modified demonstration platform to include mission computer, mesh network capable radio, and supporting hardware. - Demonstrated release 1 collaboration algorithms in real time simulation, including low bandwidth sensor fusion and collaborative tasking that maximizes system effectiveness. - Developed collaborative algorithms, tactics, concepts for communication, and human interface. - Evaluated algorithms, tactics, communication and interfaces, in non-real time simulation. ***FY 2017 Plans:*** - Continue software maturation through progressive software releases. - Validate software in hardware in the loop testing that includes mesh network, mission computer, mission sensors, and high fidelity air vehicle simulator. - Implement algorithms in first release releases of flightworthy software (release 1) hosted in mission computer compatible with demonstration platform and objective operational platforms.			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate in-flight capabilities of release 1 focused on basic limited capability software functionality verification, with initial autonomy modules including formation flight, GPS denied navigation, and other vehicle level autonomy modules such as on-board real time sensor processing, contingency management, and mission planning two real and four virtual RQ-23 Unmanned Air Vehicles (UAVs). ***FY 2018 Plans:*** - Validate next major software releases in flight. - Perform capstone demonstration involving six live and multiple virtual aircraft performing a test mission with complete software package. - Demonstrate ability of single commander to insert new objectives, modify and introduce new flight restrictions, and provide authorization to engage simulated targets. - Demonstrate the ability to integrate a software module independently developed based on their published software development toolkit. - Collaborate with operational system owners and other partners to develop early transition opportunities.			
Title: Hypersonic Air-breathing Weapon Concept (HAWC)	13.500	49.500	30.000
Description: The Hypersonic Air-breathing Weapon Concept (HAWC) program is a Joint DARPA / Air Force effort that will develop and demonstrate technologies to enable transformational changes in responsive, long-range strike against time-critical or heavily defended targets. HAWC will pursue flight demonstration of the critical 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 system designs and manufacturing approaches. HAWC technologies also extend to reusable hypersonic air platforms for applications such as global presence and space lift. The HAWC program will leverage advances made by the previously funded Falcon, X-51, and HyFly programs. 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 2016 Accomplishments:*** - Completed preliminary design of hypersonic air-breathing missile flight demonstration system. - Completed full-scale freejet propulsion system testing. - Began fabrication and testing of thermal protection. - Began detailed design of the hypersonic air-breathing missile flight demonstration system. - Began creating test-validated performance databases to anchor demonstration vehicle design. - Continued detailed plans for flight testing of the air-breathing missile demonstration system. ***FY 2017 Plans:***			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Update test-validated performance databases to anchor demonstration vehicle design. - Begin subsystem critical design of hypersonic air-breathing missile flight demonstration system. - Conduct preliminary traceability assessment between the HAWC demonstration system and the HAWC operational system. - Conduct software architecture and algorithm design. - Begin software-in-the-loop testing for the demonstration vehicle. - Begin procurement of long lead hardware for hypersonic air-breathing missile flight demonstration vehicle. - Initiate flight certification reviews with the test range. - Begin hardware-in-the-loop testing for the flight demonstration vehicle. - Initiate full-scale flight-like freejet engine testing. ***FY 2018 Plans:*** - Continue updating test-validated performance databases to anchor demonstration vehicle design. - Complete system critical design of hypersonic air-breathing missile flight demonstration system. - Continue software-in-the-loop testing for the demonstration vehicle. - Continue procurement of hardware for hypersonic air-breathing missile flight demonstration vehicle. - Continue flight certification reviews with the test range. - Continue hardware-in-the-loop testing for the demonstration vehicle. - Continue full-scale flight-like freejet engine testing. - Continue detailed plans for flight testing of the air-breathing missile demonstration system. - Begin full-scale thermal-structural testing. - Begin procurement of test assets and test support equipment. - Begin assembly, integration, and test of the air-breathing missile flight demonstration vehicle.			
Title: Tactical Boost Glide	11.200	22.800	37.600
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 to, and ideally compatibility, 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.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
FY 2016 Accomplishments: - Completed operational analysis of the Phase I performer TBG operational systems. - Completed baseline operational analysis of evolved Government Reference Vehicle (GRV). - Selected TBG demonstration test range. - Completed Phase I aerodynamic and aerothermal concept testing. - Completed first generation aero databases. - Continued risk reduction testing. - Developed initial flight test plan. - Updated Technology Maturation Plans (TMPs) and Risk Management Plans (RMPs). - Completed Preliminary Design Reviews (PDR). - Completed initial range safety documentation. ***FY 2017 Plans:*** - Conduct All-Up Round (AUR) aerodynamic and aerothermodynamic testing. - Conduct glider aerodynamic and aerothermodynamic testing. - Conduct material arcjet testing. - Complete second generation aero databases. - Prepare for Critical Design Review (CDR). - Begin procurement of hardware for demonstration vehicles. - Begin hardware in the loop (HWIL), software in the loop (SIL), and qualification testing. - Continue detailed flight test and range safety planning, coordination, and documentation. - Begin advanced operational analysis using GRV to assess new systems and technologies. - Update TMPs and RMPs. ***FY 2018 Plans:*** - Complete Critical Design Review. - Conduct aeroshell thermo-structural testing. - Conduct component aerothermal testing. - Continue procurement of hardware for demonstration vehicles. - Continue hardware in the loop (HWIL), software in the loop (SIL), and qualification testing. - Begin Assembly, Integration, and Test (AI&T). - Continue detailed flight test and range safety planning, coordination, and documentation. - Update TMPs and RMPs.			
Title: Vertical Take-Off and Landing (VTOL) Technology Demonstrator	58.800	50.500	14.700

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018

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 2016 Accomplishments:
- Flight tested and analyzed data from a sub-scale vehicle demonstrator (~330 lb.) through the hover testing phase.
- Continued preliminary design refinements leading toward detailed design of the demonstrator aircraft and associated subsystems.
- Completed preliminary design reviews of air-vehicle configuration and all major subsystems.
- Initiated aircraft software architecture, mission systems, and flight control law development and simulation.
- Developed detailed airworthiness and flight test preparation requirements in support of the full-scale technology demonstrator.
- Initiated aircraft assembly and manufacturing processes to include tooling design and fabrication.
- Initiated procurement of key long-lead items for aircraft fabrication.
- Continued refinements and development of the sub-scale vehicle demonstrator's aerodynamic model database for transition to forward flight.
- Completed detail design of the power generation system to include necessary power electronics and control features. Initiated generator fabrication.

FY 2017 Plans:
- Complete forward flight testing of the Subscale Vehicle Demonstrator.
- Continue to refine and finalize air vehicle systems design, perform subsystem critical design reviews, initiate systems fabrication.
- Perform subsystem testing to support component performance validation efforts.
- Complete testing of aircraft propulsion power generator system to verify electro-mechanical system functionality.
- 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.
- Initiate hardware/software-in-the-loop testing.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Complete vehicle management system development and avionics requirements, as well as all elements of ground control and operator/pilot stations. - Select test site(s) that can accommodate full-scale hover and transition flight, and finalize flight test plans. - Initiate fabrication and assembly of the full, complete aircraft with integrated systems and subsystems. ***FY 2018 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.			
Title: Advanced Aerospace System Concepts ***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 2016 Accomplishments:*** - Performed feasibility experiments of candidate technologies and system concepts. - Conducted trade studies and modeling and simulation for novel technologies. - Conducted proof of concept demonstrations utilizing low-cost UAVs for long endurance as well as collaborative operations. ***FY 2017 Plans:*** - Evaluate concepts of operation for enabling technology and sub-system feasibility experiments. - Research sub-system performance and conduct sub-system risk reduction testing. ***FY 2018 Plans:*** - Conduct enabling technology and sub-system feasibility experiments.	6.000	3.000	3.000
Title: Advanced Full Range Engine (AFRE)	-	12.000	35.000

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 2017 Plans:*** - Conduct test facility startup assessment. - Complete vehicle conceptual design and define TBCC ground demonstration engine performance requirements. - Begin preliminary design of the TBCC ground demonstration propulsion system, and develop ground test and associated technology development plans. - Initiate large scale common inlet design. - Design and initiate fabrication of full-scale combustor. - Initiate full-scale common nozzle design. - Initiate integrated TBCC propulsion controls development. ***FY 2018 Plans:*** - Complete fabrication and initiate testing of large-scale common inlet. - Complete fabrication and initiate testing of full-scale combustor. - Complete fabrication of full-scale nozzle. - Initiate assembly and integration of off-the-shelf turbine with full-scale nozzle. - Complete integrated propulsion controls architecture.			
Title: Aerial Reconfigurable Embedded System (ARES) ***Description:*** Current and future land and ship-to-shore operations will require rapid and distributed employment of U.S. forces on the battlefield. The Aerial Reconfigurable Embedded System (ARES) program will develop 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 resupply isolated small units. ARES is well suited for enhanced company operations concepts that would provide the warfighter/	8.000	3.500	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
team increased situational awareness for operations in an urban environment. The enabling technologies of interest developed under the ARES program includes 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 will explore opportunities for the design, development, and integration of new, key technologies and capabilities. These include adaptable landing gear concepts to enable operations from irregular landing zones and moving launch/recovery platforms, and autonomous take off and landing. The anticipated transition partners for this effort are the Army, Marine Corps, and Special Operations Forces. ***FY 2016 Accomplishments:*** - Redesigned and fabricated revised swashplate and prop-rotor control system. - Completed dynamic testing of drive train and rotor controls. ***FY 2017 Plans:*** - Complete air vehicle integration. - Perform full system hardware in the loop tests. - Support flight release development and approval process. - Perform ground tests.			
Title: Technology for Enriching and Augmenting Manned - Unmanned Systems ***Description:*** The Technology for Enriching and Augmenting Manned - Aircraft (TEAM-US) project sought to increase lethality, survivability, payload, and reach of combat aircraft by: (i) teaming them (wingmen) with advanced Unmanned Aerial Vehicles (UAVs), and (ii) enabling swarming employment and operations of manned and unmanned airborne systems. Balancing in situ battle management with highly capable, mission specific unmanned teammates would offset new threat technologies, enable more cost effective mission execution, and increase the survivability of the manned platform team leader. ***FY 2016 Accomplishments:*** - Performed operational analysis and technology maturity assessments to determine the minimum set of critical platform attributes and technology advances required of an unmanned teammate. - Investigated technology development and system attributes that matched short-term and long-term goals with specific technology solutions.	9.330	-	-
Accomplishments/Planned Programs Subtotals	165.764	182.327	155.406

D. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E *I ADVANCED AEROSPACE SYSTEMS*

D. Other Program Funding Summary ($ in Millions)

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	120.642	175.240	247.435	-	247.435	271.971	252.726	227.726	227.726	-	-
SPC-01: *SPACE PROGRAMS AND TECHNOLOGY*	-	120.642	175.240	247.435	-	247.435	271.971	252.726	227.726	227.726	-	-

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; enabling concepts include novel power/propulsion/propellants, unique manufacturing or assembly processes, and precision control of multi-payload systems.

B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	126.692	175.240	237.435	-	237.435
Current President's Budget	120.642	175.240	247.435	-	247.435
Total Adjustments	-6.050	0.000	10.000	-	10.000
• 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	-6.050	0.000			
• TotalOtherAdjustments	-	-	10.000	-	10.000

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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*

Change Summary Explanation

FY 2016: Decrease reflects the SBIR/STTR transfer.

FY 2017: N/A

FY 2018: Increase reflects Large In-Situ Manufactured Apertures (LIMA) and Blue Check new starts, offset by completion of Space Surveillance Telescope and Phoenix programs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Experimental Spaceplane One (XS-1)	18.485	40.000	60.000

Description: The XS-1 program will mature the technologies and operations for low cost, persistent and responsive space access and global reach. Past efforts have identified and demonstrated critical enabling technologies including composite or light weight 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) up to Mach 10+ flight, and 3) design capable of a 10X lower cost space access for cargos from 3,000-5,000 lbs. to low earth orbit. A key goal is validating the critical technologies for a wide range of next generation high speed aircraft enabling new military capabilities including worldwide reconnaissance, global transport, small responsive space access aircraft and affordable spacelift. The anticipated transition partners are the Air Force, Navy and commercial sector.

FY 2016 Accomplishments:

- Concluded tailored Preliminary Design Reviews of technically and programmatically viable approaches to addressing the program goals.
- Developed structural designs based on detailed finite element models.
- Performed aerodynamic Computational Fluid Dynamics analysis and conducted multiple wind tunnel tests, including large-scale transonic, supersonic, and hypersonic aeroheating campaigns to develop aerodynamic models.
- Conducted component demonstration and validation ground tests for damage-tolerant cryogenic propellant tanks, novel low-cost thermal protection mechanical design and fabrication, high-precision large-scale hybrid composite/metallic structure, wing tip aero-elasticity, and additively-manufactured propulsion components.
- Validated operational timelines and recurring cost models via discrete event simulations and upper stage unit and integration cost analyses.
- Completed the system and subsystem designs, mass properties and configuration required to support the integrated vehicle design.
- Finalized multiple viable concepts of operation including architecture, maintenance, performance, trajectories and design reference missions.
- Developed initial plan to accomplish ground operations, facility modifications and flight demonstration.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Coordinated with the Federal Aviation Administration (FAA), DoD ranges and spaceports to accomplish preliminary flight test planning. ***FY 2017 Plans:*** - Complete remaining demonstration, testing, and validation tasks including subsonic and subscale vertical takeoff and landing into a ground-fixed landing cradle in lieu of onboard landing gear, and additional tip-fin aeroelasticity modeling/correlation to establish reliable design practice based on computational methods. - Initiate detailed design program for fabrication and flight testing. - 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). - Complete cryogenic tank representative panel testing, and incorporate results in the final tank designs. - Begin propulsion system integration and preparation for ten engine firings in ten days ground test. - Initiate design for launch facilities/modifications and mature range planning including ground and flight test operations, and submittal of range documentation supporting operational requirements. - Coordinate with the FAA, DoD ranges and commercial spaceports. - Begin procurement of long lead flight and ground system hardware. ***FY 2018 Plans:*** - Mature the XS-1 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 XS-1 vehicle design for component acquisition, fabrication, assembly, and integration. - Complete propulsion qualification and acceptance testing. - Complete ten engine firings in ten days ground test. - Complete designs for ground infrastructure and mature range, ground and flight test operations planning. - Submit commercial spaceport and/or DoD range documentation. - Begin fabrication of all major subsystems and initiate acceptance test planning. - Begin integration and test of major subassemblies, flight and ground systems.			
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	29.000	45.000	59.000

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 2016 Accomplishments:*** - Developed a detailed system architecture assessment. - Began deployable antenna and software-defined radio (SDR) risk reduction efforts. - Commenced thermal cycling, power availability, and electrical system analysis. - Completed risk reduction deployable antenna pathfinder Preliminary Design Review (PDR). ***FY 2017 Plans:*** - Complete risk reduction deployable antenna proof-of-concept (POC) deployment demonstration. - Complete risk reduction deployable antenna pathfinder Critical Design Review (CDR). - Complete risk reduction deployable antenna prototype PDR. - Complete risk reduction SDR prototype PDR. - Conduct risk reduction deployable antenna prototype CDR. - Complete risk reduction SDR prototype CDR. - Conduct additional risk reduction deployable antenna POC laboratory testing. - Conduct risk reduction of demonstration system ground tests. - Conduct risk reduction SDR airborne tests. - Complete demonstration System Requirements Review (SRR). - Complete demonstration system Conceptual Design Review (CoDR). ***FY 2018 Plans:*** - Conduct risk reduction demonstration of multiple deployable antenna technologies. - Demonstrate SDR RF capability in relevant environments. - Perform risk reduction signal processing demonstration. - Integrate results from applications study and demonstration/risk reduction into prototype design. - Complete demonstration system PDR. - Complete demonstration system CDR.			
Title: Hallmark	10.000	27.000	29.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018

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 2016 Accomplishments:
- Initiated space BMC2 interactive simulation environment development.
- Conducted demonstration of integrated Government Furnished Equipment (GFE) space BMC2 tools.
- Performed demonstration of space BMC2 interactive simulation environment.
- Initiated the cognitive evaluation of operators and decision makers in a demonstration environment to maximize comprehension.
- Initiated real-time decision tools design development.

FY 2017 Plans:
- Develop sensor data fusion algorithms.
- Define course of action data scheme.
- Develop a research and development test bed to facilitate the rapid injection of new technologies into the Joint Space Operations Center (JSpOC), Joint Interagency Coalition Space Operations Center (JICSpOC), and other space operations centers.
- Complete preliminary system design.
- Develop intuitive applications and adaptive understanding capabilities for the next-generation space information fusion center.
- Define integration of space BMC2 interactive simulation environment with tools, fusion algorithms, and data schemes.
- Perform existing tool integration.
- Develop modeling and simulation infrastructure.
- Complete algorithm prototypes.
- Commence integration of existing space situational awareness, indications and warning, course of action, and decision support tools.

FY 2018 Plans:
- Integrate cognitive evaluations into tool development.
- Standardize evaluation methodology.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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.			
Title: Phoenix ***Description:*** To date, servicing operations have never been conducted on spacecraft beyond low earth orbit (LEO). A large number of national security and commercial space systems operate at geosynchronous earth orbit (GEO) altitudes; furthermore, many end-of-life or failed spacecraft drift without control through portions of the GEO belt, creating a growing hazard to operational spacecraft. Technologies for servicing of spacecraft with the expectation that such servicing would involve a mix of highly autonomous and remotely (i.e., ground-based) tele-operated robotic systems have been previously pursued. The Phoenix program will build upon these legacy technologies, tackling the more complex GEO environment and expanding beyond pure traditional servicing functions. The program will examine utilization of a new commercial ride-along system to GEO called Payload Orbital Delivery (POD) system, supporting small satellite delivery as well as hardware delivery for upgrading, repairing, assembling, and reconfiguring satellites. In addition, the program will include a LEO flight experiment focused on satlets, modular building blocks for space systems, as a path of risk reduction for modular assembly on orbit. The anticipated transition partners are the Air Force, the Army, and the commercial spacecraft and spacecraft servicing providers. ***FY 2016 Accomplishments:*** - Completed environmental testing of early LEO satlet experiment. - Developed POD payload hardware and initiated environmental testing. ***FY 2017 Plans:*** - Deliver early LEO satlet experiment equipment to launch integrator. - Launch early LEO satlet experiment and conduct experiment operations. - Complete delta critical design review of satlets per lessons learned from LEO experiment. - Complete ground testing of POD hardware and deliver for launch. - Launch POD and conduct on-orbit testing. - Transition residual satlet hardware to U.S. Army.	23.300	5.402	-
Title: Robotic Servicing of Geosynchronous Satellites (RSGS) ***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, an outgrowth of the Phoenix program budgeted within this Project, seeks to establish the capability to acquire robotic services in GEO suitable for a variety of potential servicing tasks, in full collaboration and	11.261	51.838	79.250

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 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 2016 Accomplishments:*** - Continued development of servicer robotic payload initiated under the Phoenix program. - Conducted studies of suitable satellites to carry the robotic payload. - Established system requirements for the robotic payload in accordance with primary missions. - Established initial government membership of CONFERS and defined roles and responsibilities. ***FY 2017 Plans:*** - Select commercial partner as provider of satellite to carry robotic payload, and owner/operator of system on orbit. - Develop interface definition between robotic payload and satellite. - Begin flight software coding. - Begin development of operator workstations. - Begin procurement of long-life space hardware for robotic payload and instrumentation. - Develop comprehensive test plan for robotics and for integrated system. - Complete structural analysis of robotic arms and tool changer, prepare detailed designs, and begin fabrication. - Design, acquire and test payload electronic systems. - Select a Secretariat to stand up CONFERS and begin standards development. ***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 arms 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.			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Publish first draft of consensus on-orbit safety standards through a qualified standards development organization.			
Title: Large In-Situ Manufactured Apertures (LIMA) ***Description:*** The Large In-Situ Manufactured Apertures (LIMA) program seeks to demonstrate the structural fabrication of a high-performance radio frequency (RF) antenna attached to a microsatellite. Larger and more directional than any comparable antenna that could be deployed from a microsatellite platform, LIMA would deliver high-performance communication and data services to the dismounted warfighter at significantly lower cost while enabling signal intelligence (SIGINT) capability. The program will complete a low Earth orbit (LEO) small-scale demonstration in which a commercial communications microsatellite is augmented in situ (i.e., on orbit, in flight) with an antenna that is completely fabricated in space, and will prove by computational modeling and simulation how a constellation of full-scale microsatellites with In-situ fabricated apertures may be applied to close a high-performance RF link directly to a cellular hand set in a global tactical communications network. The program seeks to achieve greater than 50% savings in individual 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:*** - Develop and demonstrate in-space fabrication process technologies in ground-based trials, including validation of key process elements in flight-like environments. - Design a compact dual-use military and commercial transponder payload and fabrication substrate (platen) for the commercial microsatellite to interface with the in-space-fabricated antenna. - 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.	-	-	10.185
Title: Blue Check ***Description:*** The Blue Check program will develop space technologies to determine spacecraft identification and state data, completely independent of the spacecraft. Capabilities developed will support integrating spacecraft-derived information into the space domain awareness picture. Key efforts focus on the development of an identification and information device for every space object placed in orbit to provide accurate data. Resulting capabilities will aid in rapid determination of space objects, particularly in the case of multi-spacecraft deployments. Inherent to the space identification technology is the ability to provide forensic data for failed or anomalous spacecraft. Other areas to be investigated include leveraging small satellite mega-constellations and their networks to provide ID, state, and sensor data in support of this and other applications. ***FY 2018 Plans:*** - Initiate system architecture and trade studies.	-	-	10.000

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Begin prototype and ground system design development.			
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 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 system transitioned to Air Force Space Command (AFSPC). 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. ***FY 2016 Accomplishments:*** - Improved Wide Field Camera (WFC) #2 for enhanced SST capability. - Installed and characterized WFC #2 at White Sands Missile Range (WSMR) site and began demonstration of performance improvement. - Developed plan to transition SST to AFSPC. ***FY 2017 Plans:*** - Complete demonstration of WFC #2 performance improvement at White Sands Missile Range (WSMR) site. - Support Joint Space Operations Center (JSpOC) data delivery. - Complete transition to AFSPC.	12.900	6.000	-
Title: Airborne Launch Assist Space Access (ALASA) ***Description:*** The ALASA program sought to make access to space more affordable by significantly reducing the cost of launch for <200 kg payloads to low earth orbit, with an ultimate goal of $1M for 50kg. In addition, the program sought to improve the responsiveness of space access by reducing the interval from call-up to launch to a single day. ***FY 2016 Accomplishments:*** - Performed propellant characterization to determine safe and effective operating envelope.	8.830	-	-

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Performed development of planning tools, and autonomous flight termination technology which allow for more operational flexibility and decrease recurring launch costs. - Assessed alternative launch systems.			
Title: Space Domain Awareness (SDA) ***Description:*** The goal of the Space Domain Awareness (SDA) program was to develop and demonstrate an operational framework and responsive defense application to enhance the availability of vulnerable space-based resources. SDA investigated revolutionary technologies in two areas: 1) advanced space surveillance sensors to better detect, track, and characterize space objects, with an emphasis on deep space objects, and 2) space surveillance data collection, data archival, and data processing/ fusion to provide automated data synergy. The SDA program leveraged data fusion and advanced algorithms developed under the Space Surveillance Telescope (SST) program, and also sought to exploit new ground-breaking technologies across the electromagnetic spectrum and utilize already existing sensor technology in nontraditional or exotic ways. ***FY 2016 Accomplishments:*** - Completed an initial capability demonstration of a collaborative network of distributed sensors. - Integrated all data providers and first generation algorithms on the SDA database to autonomously detect biases, estimate uncertainties, and leverage non-accredited information for real time SDA. - Expanded the portfolio of modalities contributing to SDA to include RADAR data providers. - Developed technology and execution plan for demonstration of Low Inclined Low-Earth-Orbit Objects (LILO) sensor. - Conducted multiple capability demonstrations of collaborative network of distributed sensors and users. - Performed and documented analysis of algorithm performance.	6.866	-	-
Accomplishments/Planned Programs Subtotals	120.642	175.240	247.435

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	78.984	49.807	79.173	-	79.173	81.110	126.359	165.172	165.172	-	-
MT-12: *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	-	2.470	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	76.514	49.807	79.173	-	79.173	81.110	126.359	165.172	165.172	-	-

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, actuators and gear drives 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 MicroElectroMechanical Systems (MEMS) and Integrated Microsystems Technology project funded a broad, cross-disciplinary initiative to merge computation, power generation, sensing, and actuation to realize new technologies for perceiving and controlling weapons systems and battlefield environments. Using fabrication processes and materials similar to those used to make microelectronic devices, this project applied the advantages of miniaturization and integrated microelectronics to the design and construction of integrated electromechanical and electro-chemical-mechanical systems. The project addressed issues that ranged from the scaling of devices and physical forces to new organization and control strategies for distributed, high-density arrays of sensor and actuator elements. The resulting technologies will be applied to microscale precision, navigation, and timing systems; microscale components that survive harsh environments; and tactically-relevant MEMS systems that operate in a variety of thermal and vibration environments.

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.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	76.021	49.807	74.033	-	74.033
Current President's Budget	78.984	49.807	79.173	-	79.173
Total Adjustments	2.963	0.000	5.140	-	5.140
• 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	6.001	0.000			
• SBIR/STTR Transfer	-3.038	0.000			
• TotalOtherAdjustments	-	-	5.140	-	5.140

Change Summary Explanation

FY 2016: Increase reflects reprogrammings offset by the SBIR/STTR transfer.

FY 2017: N/A

FY 2018: Increase reflects Rapid Array Development (RAD), Radio Frequency Collaborative Unmanned Distributed System (RF CLOUDS), and Efficient Ultra-Compact Laser-Integrated Diodes (EUCLID) new start programs.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	Project (Number/Name) MT-12 / *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
MT-12: *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	-	2.470	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The MicroElectroMechanical Systems (MEMS) and Integrated Microsystems Technology project funded a broad, cross-disciplinary initiative to merge computation, power generation, sensing, and actuation to realize new technologies for perceiving and controlling weapons systems and battlefield environments. Using fabrication processes and materials similar to those used to make microelectronic devices, this project applied the advantages of miniaturization and integrated microelectronics to the design and construction of integrated electromechanical and electro-chemical-mechanical systems. The project addressed issues that ranged from the scaling of devices and physical forces to new organization and control strategies for distributed, high-density arrays of sensor and actuator elements. The resulting technologies could be applied to microscale precision, navigation, and timing systems; microscale components that survive harsh environments; and tactically-relevant MEMS systems that operate in a variety of thermal and vibration environments.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Micro-Technology for Positioning, Navigation, & Timing (micro-PNT)	2.470	-	-

Description: The Micro-Technology for Positioning, Navigation, & Timing (micro-PNT) program developed low-cost, size, weight, and power (CSWaP) sensors and timing devices for navigation in GPS-degraded environments. The program primarily focused on improving microelectromechanical systems (MEMS) sensors, which currently display limited performance but excellent CSWaP, and miniaturizing atomic gyroscopes and clocks, which are currently limited to laboratory experiments because of their complexity and high CSWaP. To enhance MEMS sensor performance and realize low-CSWaP atomic sensors, the program developed novel microfabrication processes, investigated new material systems, and contributed to the understanding of error sources. Innovative microfabrication techniques development allowed co-fabrication of dissimilar devices on a single chip that enabled the required clocks, gyroscopes, accelerometers, and calibration components to integrate into a small, low-power architecture. Ultimately, low-CSWaP inertial sensors and clocks enabled ubiquitous guidance and navigation on all platforms, including guided munitions, unmanned aerial vehicles (micro-UAVs), and mounted and dismounted soldiers. Service labs have been actively involved throughout the program and are facilitating transition of micro-PNT technology to Service-led programs for further development and testing.

FY 2016 Accomplishments:

- Demonstrated an atom interferometer gyroscope meeting the Phase 2 angle random walk milestone in a package smaller than 200 cm3 (approximately smartphone-sized).

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-12 / *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrated a 3D birdbath resonator with ringdown time > 100 seconds and developed control electronics to implement a rate-integrating micro-gyroscope. - Demonstrated MEMS gyroscopes and accelerometers, in a single-chip MEMS inertial measurement unit, with tactical-grade performance.			
Accomplishments/Planned Programs Subtotals	2.470	-	-

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	76.514	49.807	79.173	-	79.173	81.110	126.359	165.172	165.172	-	-

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 2016	FY 2017	FY 2018
Title: Endurance	24.000	15.307	10.000

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 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. An applied research component of the program, which focuses on miniaturizing and reducing the weight of subsystems, is budgeted in PE 0602702E, Project TT-06.

FY 2016 Accomplishments:
- Built and tested critical subsystems; all subsystems met or exceeded required specifications.
- Completed integration of subsystems into the pod structure and ran initial connection checks.
- Completed test plan for field testing at White Sands Missile Range.

FY 2017 Plans:
- Test the brassboard laser weapon system at outdoor test ranges against a representative set of static and live-fire threat targets.
- Assess brassboard system performance in live-fire testing.

FY 2018 Plans:

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Develop a preliminary engineering design for a flight-prototype of a pod-mounted laser weapon system. - Perform environmental testing to assess performance under stressing vibrational and temperature conditions.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM)	13.000	14.000	20.000

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 2016 Accomplishments:
- Completed preliminary design, fabrication, and characterization of MEMS gyroscopes meeting stability and repeatability specifications consistent with navigation-grade performance.

FY 2017 Plans:
- Perform, fabrication and characterization of MEMS inertial sensors meeting stability and repeatability specifications consistent with navigation-grade performance.
- Demonstrate and deliver five MEMS gyroscopes meeting stability and repeatability specifications consistent with navigation-grade performance.
- Demonstrate and deliver five MEMS accelerometers meeting stability and repeatability specifications consistent with navigation-grade performance.

FY 2018 Plans:

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Deliver five MEMS gyroscopes meeting environmental requirements (vibration, shock survivability, operation over temperature). - Deliver five MEMS accelerometers meeting environmental 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.			
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. ReImagine builds upon the multifunctional imager concept in the Pixel Network (PIXNET) program which is budgeted in PE 0602716E, Project ELT-01. Where PIXNET focused on multiple functions in the detector layer, ReImagine adds 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 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 2016 Accomplishments:*** - Completed the preliminary study phase that will develop application requirements, as well as the design of a prototype camera. ***FY 2017 Plans:*** - Design, and deliver the GFE digital ROIC configuration software to industry performers. - Successfully map multi-function processing algorithms to the ROIC layer using custom software tools. ***FY 2018 Plans:*** - Begin initial development of the 2nd generation ReImagine chip, which will expand functionality of the data flow options off of the ROIC while providing in-sensor processing options. - Begin process development for 3-D integration of the ReImaging prototype camera.	7.042	14.500	22.173

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Demonstrate the benefits of multifunctional capability, particularly showing the ability to change from time sensing to spatial sensing dynamically and focusing on only relevant regions of interest within the camera view.			
Title: Rapid Array Development (RAD) ***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 flexible array testbed that will be the common hardware platform for an applications development environment. - Initiate development of a processing platform capable of executing EM algorithms, array configuration, data flow and end-user interactions. - Initiate development of cloud-based applications to facilitate rapid re-configuration of an array platform without having to modify existing hardware. - 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.	-	-	12.000
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.	-	-	5.000

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
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.			
Title: Radio Frequency Collaborative Unmanned Distributed System (RF CLOUDS)	-	-	10.000
Description: The Radio Frequency Collaborative Unmanned Distributed System (RF CLOUDS) program aims to significantly reduce the size, weight and power (SWaP) of RF components to enable electronic warfare (EW), communications, and radar for next-generation unmanned autonomous systems (UAS). High-performance RF components enable the DoD to deploy sophisticated payloads on high-value platforms. However, new DoD concepts of operation require a significant reduction in RF hardware power consumption and size. RF CLOUDS will develop the components required for swarms of small autonomous systems. These RF components would work together across a swarm of nodes, sharing measurements of the electromagnetic spectrum, combining radiated energy to transmit signals, and managing unwanted energy emissions to avoid detection. This node-based, collaborative approach is expected to allow for enhanced RF system performance while lowering the performance requirement and cost for each individual node. These improvements would allow DoD to transition from placing high-performance RF hardware on a few high-value platforms to deploying a large number of low-cost autonomous nodes for pervasive stand-in electromagnetic access of denied areas. ***FY 2018 Plans:*** - Demonstrate the combining of distributed receiver data from COTS hardware to increase the sensitivity, dynamic range and geolocation estimation accuracy over single node performance. - Demonstrate non-signal assisted distributed beamforming to inform design of chip-scale transmitter with integrated node-to-node time transfer.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Design chip-scale real-time spectrum analyzer with direction finding capability and <1 W power consumption.			
Title: FLASH - Scaling Fiber Arrays at Near Perfect Beam Quality	16.000	3.500	-
Description: The FLASH program aims to demonstrate 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. The laser system would significantly enhance the platforms defensive capabilities against electro-optical/infrared (EO/IR) guided missiles. 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 will pursue two major thrusts. First, FLASH aims to greatly reduce the size and weight of high-power fiber laser amplifiers, increase their power efficiency and improve their resistance to shock, vibration and acoustic stresses found on military platforms. Second, FLASH aims to fabricate an array of these amplifiers and integrate 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.			
FY 2016 Accomplishments: - Completed a critical design for a >40 kW transportable, packaged laser system. - Built and tested coherent beam combining subsystem and achieved high power with excellent beam quality and combining efficiency. - Built and tested line-replaceable battery unit powering a line-replaceable fiber amplifier assembly, successfully combining 4 fiber amplifier outputs with high efficiency and excellent beam quality. - Began assembly of line-replaceable battery units and line replaceable amplifier units after successful testing of first production units. - Integrated thermal subsystem, primary electronic control, and low power signal fibers into mechanical assembly.			
FY 2017 Plans: - Complete line-replaceable fiber amplifier units and integrate into >40 kW transportable, packaged laser system. - Test and demonstrate the >40 kW transportable, packaged laser system.			
Title: Diverse & Accessible Heterogeneous Integration (DAHI)	14.472	2.500	-
Description: The Diverse Accessible Heterogeneous Integration (DAHI) program is developing 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 would enable 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, builds on previous DARPA and commercial			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
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 focuses on establishing a technologically mature manufacturing path for integrating a wide array of materials and devices, including CS, on a common substrate. Relevant manufacturing processes would be made available to a wide variety of designers from the DoD laboratories, federally funded research and development centers, academia and industry. DAHI will also support 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. ***FY 2016 Accomplishments:*** - Completed development of a high-yield, high-reliability accessible manufacturing process flow which will be transitioned to a self-sustaining foundry activity providing heterogeneously integrated circuits with four materials/device technologies. - Completed demonstration of capability for supporting multi-project wafer runs using the heterogeneous foundry service under development. ***FY 2017 Plans:*** - Finalize refinements of yield and reliability and coordinate with self-sustaining foundry activity to ensure successful transition of heterogeneous integration technology. - Finalize the development of seamless process design kits and integrated design flows to facilitate the use of the foundry service by external users.			
Title: Direct SAMpling Digital ReceivER (DISARMER) ***Description:*** The Direct SAMpling Digital ReceivER (DISARMER) program aimed to design, fabricate and test a digital wideband receiver which captures and digitizes electromagnetic (EM) spectrum signals with potential applications for electronic warfare and signals intelligence. The hybridized receiver would integrate photonic (light-manipulating) and electronic components in a standard form factor. Conventional digital wideband receivers are limited in their dynamic range, which determines their resilience to jammers and drives their ability to detect and record faint signals. DISARMER sought to overcome this limitation by employing an ultra-stable optical clock, which would allow systems to sample the spectrum with greater precision. The DISARMER receiver would improve spur-free dynamic range 100x over the state of the art and prove capable of coherently sampling the entire, tactically-relevant, X-band (8-12 GHz) portion of the spectrum. Such a wide-bandwidth, high-fidelity receiver would also have the potential to drastically reduce the cost, size and weight of electronic warfare and signals intelligence systems. ***FY 2016 Accomplishments:*** - Conducted a demonstration of direct sampling of a 4 GHz-wide bandwidth signal at 10 effective bits of fidelity.	2.000	-	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Tested system performance across both baseband and the entire X-band (8-12 GHz).			
Accomplishments/Planned Programs Subtotals	76.514	49.807	79.173

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-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	201.635	155.081	106.787	-	106.787	137.904	99.503	127.183	203.483	-	-
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	94.626	93.781	55.928	-	55.928	88.419	80.233	117.183	203.483	-	-
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	107.009	61.300	50.859	-	50.859	49.485	19.270	10.000	0.000	-	-

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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	201.335	155.081	185.554	-	185.554
Current President's Budget	201.635	155.081	106.787	-	106.787
Total Adjustments	0.300	0.000	-78.767	-	-78.767
• 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	8.379	0.000			
• SBIR/STTR Transfer	-8.079	0.000			
• TotalOtherAdjustments	-	-	-78.767	-	-78.767

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016: Increase reflects reprogrammings offset by the SBIR/STTR transfer.

FY 2017: N/A

FY 2018: Decrease reflects completion of the Wireless Network Defense program in FY 2017 and other program rephasing.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	94.626	93.781	55.928	-	55.928	88.419	80.233	117.183	203.483	-	-

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 2016	FY 2017	FY 2018
Title: 100 Gb/s RF Backbone	19.824	17.638	6.268
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 2016 Accomplishments: - Continued to reduce the size, weight, and power of the system components to metrics consistent with high altitude, long endurance aerial platforms.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Conducted laboratory tests of merged higher-order modulation and spatial multiplexing technologies. - Initiated prototype performance evaluation planning for mountain-to-ground tests at a Government test range. - Developed initial pointing, acquisition, and tracking capabilities to support mobile link operation. - Conducted initial prototype testing using multiple system configurations to characterize initial system performance. ***FY 2017 Plans:*** - Refine software and firmware of constituent technologies based on results of initial testing. - Conduct multiple field tests of the prototype hardware at a Government test range. - Integrate prototype onto test aircraft and conduct air-to-ground testing at a Government test range. ***FY 2018 Plans:*** - 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.			
Title: Advanced RF Mapping	14.964	13.880	6.322
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 will develop and demonstrate new concepts for sensing and manipulating the RF environment based on distributed rather than centralized collection. This approach will take advantage of the proliferation of RF devices, such as radios and cell phones, on the battlefield. To leverage these existing devices effectively, the program will develop new algorithms that can map the RF environment with minimal communication load between devices. The Advanced RF Mapping program will also develop 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. Building upon technologies investigated within other programs within this project, the Advanced RF Mapping program will enable both offensive and defensive operations in complex RF environments. Advanced RF Mapping technology is planned to transition to the Services. ***FY 2016 Accomplishments:*** - Conducted RF Mapping tactical demonstrations.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Developed a baseline sensor management user interface and command and control software layer to enable mission planners to task RF devices and configure the RF mapping system. - Developed a baseline user interface for presenting RF mapping information to tactical units. - Developed software for interconnecting the RF mapping capability with other tactical Electronic Warfare (EW) systems enabling cueing and results sharing. - Developed interface control documentation (ICD) that permitted vendors to independently integrate third party RF devices and applications for use as additional RF Mapping sensors. - Developed software for storing RF maps and querying the stored data for both tactical use and post-mission analysis. ***FY 2017 Plans:*** - Enhance the baseline sensor management and RF Mapping user interfaces for the Services. - Develop final Command and Control (C2) software configurations to integrate RF Mapping sensors into existing Service architectures, to enhance RF sensing capacity. - Integrate additional third party sensors, such as U.S. Marine Corps and Special Operations Command (SOCOM) Counter Remotely Controlled Improvised Explosive Device Electronic Warfare (CREW) into the RF Mapping architecture. ***FY 2018 Plans:*** - Continue to participate in Service exercises to demonstrate the system's ability to provide RF sensing and manipulation and inform new tactics, techniques and procedures. - Transition Advanced RF Mapping or elements to the Services, primarily Marine Corps, and SOCOM for operational use.			
Title: Communication in Contested Environments (C2E)	19.269	10.763	4.159
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			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
party native application and waveform developers to contribute their own communications technologies. Technologies from this program are planned to transition to the Services. ***FY 2016 Accomplishments:*** - Completed development of advanced network processing functions for implementation in an Application Specific Integrated Circuit (ASIC). - Created novel LPD/AJ capabilities and initiated integration into C2E radios. - Matured design of ASIC. - Released updated version of the combined software architecture, development environment and tool set, verification environment, and repository. - Demonstrated Heterogeneous Networking LPD/AJ features. - Continued development of the C2E waveforms. - Demonstrated airborne tactical network waveform interoperability on the C2E reference architecture. - Enhanced the software development environment to improve functionality and ease of use. ***FY 2017 Plans:*** - Finalize verification testing and system integration of the C2E Common-modem Hardware Integrated Library (CHIL). - Complete development and integration of the C2E CHIL on the Ruggedized Flight System radios. - Initiate development and testing of the Ruggedized Flight System radio with airborne tactical waveforms. ***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.			
Title: Dynamic Network Adaptation for Mission Optimization (DyNAMO)	12.075	19.787	16.998
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			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
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 2016 Accomplishments:*** - Commenced development of candidate near-real-time optimization algorithms to improve network reliability and efficiency when affected by advanced threats. - Initiated analysis of candidate inter-network coordination and decentralized network services for operation in the presence of a peer adversary. - Commenced development of mission-based network architecture control and information delivery mechanisms. - Initiated development of an emulation environment that will be used to evaluate both individual DyNAMO technology developments and system solutions. ***FY 2017 Plans:*** - Continue development of near-real-time optimization algorithms. - Develop and integrate inter-network coordination and decentralized network services. - Continue development and integration of mission-based network architecture control and information delivery mechanisms. - Conduct testing of individual technology developments in an emulation environment. - Conduct system-level emulation test of system with initial instantiation of internetwork coordination and mission-based control. - Initiate integration to support hardware-in-the-loop test of system with initial instantiation of internetwork coordination and mission-based control. ***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 internetwork coordination, mission-based control, and real-time optimization. - Conduct flight test of integrated system with instantiations of internetwork coordination, mission-based control, and real-time optimization. - Conduct system-level emulation test of advanced network infrastructure with final instantiation of internetwork coordination, mission-based control, and real-time optimization.			
Title: Spectrum Efficiency and Access	16.990	13.530	8.689
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			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018

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 DoD.

FY 2016 Accomplishments:

- Modeled and assessed methods for automatically mitigating interfering transmissions caused by malfunctioning or misconfigured communications devices.
- Developed and assessed updated strategies to defend military systems against threats created by sharing spectrum information between military radars and commercial communications systems.
- Analyzed and developed baseline version of control system to manage spectrum sharing mechanisms.
- Conducted laboratory demonstrations of spectrum sharing among conforming radar and military and commercial communications systems that incorporates multiple sharing mechanisms.
- Performed initial vulnerability assessment of the spectrum sharing control system and sharing mechanisms through simulated attacks.
- Modeled and assessed performance of jointly designed military radar and military communications systems operating in a shared spectrum allocation in electronic countermeasure operating environments.

FY 2017 Plans:

- Develop improved version of the Command and Control (C2) system to manage spectrum sharing and coordination mechanisms between U.S. and coalition military systems.
- Integrate hardware and software necessary to support system C2, sharing and coordination mechanisms, software application needs, security level requirements, and best electronic protections technologies and techniques.
- Conduct field demonstrations with candidate systems that incorporate multiple spectrum sharing and coordination mechanisms.
- Develop transition plan and continue engagement with Navy and Army stakeholders.

FY 2018 Plans:

- Update candidate system hardware and software necessary to mitigate overall system vulnerability.
- Conduct field demonstrations in operationally representative environments with candidate systems that incorporate multiple spectrum sharing and coordination mechanisms.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Implement transition plans with identified Navy and Army stakeholders.			
Title: Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE)	-	7.000	13.492
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 2017 Plans:*** - Develop the network architecture and software for secure and resilient sharing of information within coalition partners. - Define the security environment and overall system security architecture. ***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 of information at multiple security levels. - Develop the architecture and software for automated configuration of multiple security levels across coalition networks. - Perform red team assessment of the security of the software architecture to characterize detectable vulnerabilities and compliance with SHARE program objectives.			
Title: Wireless Network Defense	11.504	11.183	-
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. Based on initial work under this effort, the Spectrum Efficiency and Access program in this PE/Project was created to enable reliable operation of military and commercial communications and radar systems when occupying the same spectrum bands. As part of the Advanced Networks technologies effort, the Wireless Network Defense program increases 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 is mitigation of advanced threats particular to the security of wireless networks. The program intends to leverage the capabilities of the dynamic network to identify sources of misinformation, whether malicious or due to poor configuration, across the functional components			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
of the complex system, and mitigate the corresponding effects. Technologies developed under this program will transition to the Services. ***FY 2016 Accomplishments:*** - Increased severity of attacks on prototype system and continued to test resilience in laboratory environment. - Completed integration of candidate algorithms and protocols to prepare for field experiments. - Refined protection mechanisms based on test findings and began development of systems for transition to military tactical radios. - Began integration with military tactical radios, quantifying the performance impact through experiments. ***FY 2017 Plans:*** - Perform field testing of the radios and the radio network, using Wireless Network Defense to detect and mitigate network attacks against the radios. - Perform final test of the mixture of hardware and emulated radios, demonstrating the ability of Wireless Network Defense to detect and mitigate network attacks in large, heterogeneous networks of tactically relevant radios to facilitate transition to the Army and Marine Corps.			
Accomplishments/Planned Programs Subtotals	94.626	93.781	55.928

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	107.009	61.300	50.859	-	50.859	49.485	19.270	10.000	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 2016	FY 2017	FY 2018
Title: Classified DARPA Program	107.009	61.300	50.859
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2016 Accomplishments:*** Details will be provided under separate cover. ***FY 2017 Plans:*** Details will be provided under separate cover. ***FY 2018 Plans:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	107.009	61.300	50.859

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	411.060	428.894	439.386	-	439.386	420.714	388.717	347.781	339.315	-	-
NET-01: *JOINT WARFARE SYSTEMS*	-	59.762	72.916	67.114	-	67.114	114.914	155.974	195.958	192.992	-	-
NET-02: *MARITIME SYSTEMS*	-	139.053	138.303	138.112	-	138.112	118.694	83.543	97.223	142.323	-	-
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	212.245	217.675	234.160	-	234.160	187.106	149.200	54.600	4.000	-	-

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	425.861	428.894	410.027	-	410.027
Current President's Budget	411.060	428.894	439.386	-	439.386
Total Adjustments	-14.801	0.000	29.359	-	29.359
• 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	-7.394	0.000			
• SBIR/STTR Transfer	-7.407	0.000			
• TotalOtherAdjustments	-	-	29.359	-	29.359

Change Summary Explanation

FY 2016: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2017: N/A

FY 2018: Increase reflects expansion of classified programs.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
NET-01: *JOINT WARFARE SYSTEMS*	-	59.762	72.916	67.114	-	67.114	114.914	155.974	195.958	192.992	-	-

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 2016	FY 2017	FY 2018
Title: System of Systems Integration Technology and Experimentation (SoSite)	36.109	35.741	27.771
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 2016 Accomplishments: - Completed development of architecture demonstration plan, including range and platform options.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Developed a System Integration Laboratory (SIL) to support Government verification and validation of system of systems architectures. - Completed the development of system of systems synthesis and integration tools and protocols. - Completed prototype architecture designs to implement the system of systems concept. - Initiated experimentation in constructive and virtual environments to validate system of systems approach. - Verified prototype of system of systems architectures in M&S environments. - Identified the most promising alternative systems architectures, designs, tools, and protocols for the maritime environment. - Explored system architectures for interdiction of small, unmanned aerial systems in complex urban environments.			
FY 2017 Plans: - Prepare detailed live flight experimentation plans establishing system of systems risk reduction test objectives, experiment designs, required test articles and experiment support assets, and analysis plans. - Secure test articles for offensive counter-air flight test experiments: manned and unmanned platforms, and experimental mission systems from DARPA and Service Science and Technology programs. - Secure or develop models of test articles to support laboratory and ground checkout prior to live flight. - Secure support assets required for flight test experiments: ranges and range instrumentation, frequency and airspace authorizations, pilots, virtual and constructive simulation facilities. - Conduct virtual integration and laboratory checkout of system of systems architectures using test article models to verify those architectures will satisfy risk reduction experimentation objectives. - Integrate test articles into system of systems architectures and conduct ground checkout prior to live flight. - Conduct experiments of system of systems architectures for offensive counter air missions in live flight, augmented with virtual and constructive simulation of test articles not ready for live flight; analyze experiment outcomes and document accomplishment of risk reduction objectives. - Develop a System Integration Laboratory (SIL) to support Government verification and validation of system of systems architectures. - Assess in SIL the capability of new formal verification techniques and engineering tools to validate integration of constituent systems into a system of systems. - Develop technologies to facilitate multi-level open architecture security M&S.			
FY 2018 Plans: - 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.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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.			
Title: Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE)	12.429	26.448	18.596
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 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 2016 Accomplishments:*** - Completed initial development of algorithms and prototypes for distributed planning and assessment components. - Developed models and simulation capability for testing, analysis, and validation of a distributed system operating in a communications-challenged environment. - Implemented the framework designs into a software prototype. - Tested and evaluated candidate software frameworks and components. - Commenced development of decision support tools for distributed operational planning. ***FY 2017 Plans:*** - Develop experiments to highlight the planning and assessment capabilities in both a distributed and communications-challenged environment. - Continue integration efforts with the prototype framework.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Continue development of planning tools that combine planning for strike, reconnaissance and electronic warfare in a distributed environment. - Continue development of assessment capabilities that automatically track plan execution and alert command and control cells when plans are likely to change. - Demonstrate the ability of small, distributed staffs to plan and manage large-scale operations within an established Air Force modeling and simulation environment. - Develop planning and estimation algorithms and initial prototypes to support the maritime counter-ISR mission. ***FY 2018 Plans:*** - Develop a fully integrated software system prototype to demonstrate a distributed concept of operations. - 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. - 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. - Conduct multiple simulation-based experiments with USPACFLT to facilitate transition to the Navy.			
Title: Retrodirective Arrays for Coherent Transmission (ReACT)	11.224	10.727	5.984
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 program builds upon technology developed under the Arrays at Commercial Timescales (ACT) program, which is budgeted in PE 0602716E, Project ELT-01, and will culminate with a flight demonstration of distributed beamforming. The ReACT technology is planned to transition to the Air Force and Navy. ***FY 2016 Accomplishments:*** - Completed development of algorithms and hardware for coherent beamforming under mobile environments. - Designed vibration compensation circuit for feedback control. - Identified phenomenological barriers (frequency, motion, and vibration) and validated transition opportunities. - Demonstrated system performance over-the-air in mobile ground environments at extended ranges.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Initiated program transition with the Navy. ***FY 2017 Plans:*** - Design predictive algorithms for broadband channel estimation. - Design control and feedback circuits to track highly mobile targets based on the target's emissions. - Integrate hardware for a dynamic airborne demonstration on multiple aircraft. - Continue modeling and analysis study into maritime applications, and the ground-to-airborne scenario. - Investigate multiple coherent node transition paths with the Air Force. - Integrate tracking algorithms for target motion, preparing for air-to-ground demonstration of capability. - Explore alternative jamming methods against surveillance radars. ***FY 2018 Plans:*** - Integrate node capabilities onto surrogate airborne transmission platform and hardware. - Operate airborne array at suitable test facility with real world scenario/environment. - Finalize transition package for Navy technology demonstration group.			
Title: Systems of Systems-Enhanced Small Units (SESU) ***Description:*** The Systems of Systems-Enhanced Small Units (SESU) program will develop and demonstrate capability to enable a small unit of U.S. forces to prevail when severely over-matched by a much larger adversary force. SESU-developed capabilities will provide the small unit with better indications and warning of an invasion or attack, the means to deter such an attack, and if the attack occurs, the ability to delay the adversary advance to allow sufficient time for reinforcements. Technologies to accomplish this will include command, control, & communications (C3) to 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 technology to enable manned-unmanned teaming with a focus on C3 and autonomy of the unmanned capabilities without placing an undue burden on the human operators. SESU technologies will be integrated using systems of systems principles developed under the System of Systems Integration Technology and Experimentation (SoSite) program, also budgeted in this Program Element/Project. Testing and experimentation will be conducted with Service partners, and technologies produced by this program will be transitioned to the Services. ***FY 2018 Plans:*** - Develop baseline mission scenarios and SESU components. - Begin selection of maturing technology and initiate tailoring and integration into system concepts. - Define experimentation plan. - Demonstrate initial technologies in a simulated environment.	-	-	7.363
Title: Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS)	-	-	7.400

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 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 wargaming platform development for company-level and above resolution. - Begin development of initial models for multiple warfighting functions. - Demonstrate against a virtual adversary.			
Accomplishments/Planned Programs Subtotals	59.762	72.916	67.114

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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COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
NET-02: *MARITIME SYSTEMS*	-	139.053	138.303	138.112	-	138.112	118.694	83.543	97.223	142.323	-	-

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 2016	FY 2017	FY 2018
Title: Hydra	33.931	32.682	7.558

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. Technologies from this program will transition to the Navy.

FY 2016 Accomplishments:
- Started development of prototype modular enclosure.
- Conducted in-water tests of critical components.
- Completed preliminary design review for undersea payload.
- Completed component testing on undersea payload technologies.
- Completed critical design review for air vehicle payload.
- Conducted flight tests of the air vehicle.
- Conducted air vehicle capsule pop-up tests in water.
- Developed alternative deployment method for selected Hydra payloads.

FY 2017 Plans:
- Complete development and demonstrate prototype modular enclosure.
- Complete a full air vehicle flight test.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Launch air vehicle from undersea. - Build prototype hardware to demonstrate alternative deployment method for selected Hydra payloads. - Build prototype hardware for additional payload experimentation. ***FY 2018 Plans:*** - Continue testing of alternative payload deployment methods, and conduct at-sea demonstration. - Complete testing of undersea-launched air vehicle.			
Title: Hybrid Multi Material Rotor Full Scale Demonstration (HyDem)	14.000	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 which 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. This program will transition to the Navy. ***FY 2016 Accomplishments:*** - Completed manufacturing of the full-scale propulsor component. - Assessed structural and shock qualification of the propulsor component. - Completed shock building block testing. - Initiated development of advanced concepts seeking to improve performance and affordability. - Initiated long-term environment exposure monitoring test program. ***FY 2017 Plans:*** - Deliver full-scale propulsor component to the Navy for integration into a Virginia Class submarine. - Provide integration support for the propulsor component. - Complete structural building block testing. - Initiate Ohio Replacement technology applicability study. - Complete shock qualification of propulsor component. - Assess advanced concepts using material systems in non-propulsor applications. - Transition long-term environmental exposure monitoring program to the Navy.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Initiate design efforts for an improved full scale component. ***FY 2018 Plans:*** - Complete Critical Design Review (CDR)-level design of improved full scale component. - Complete naval shafting applications study. - Deliver a scaled shafting component.			
Title: Tactical Undersea Network Architecture	23.742	21.173	19.973
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. By leveraging techniques explored under the Distributed Agile Submarine Hunting (DASH) program budgeted within this PE/Project, the Tactical Undersea Network Architecture 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 Architecture program will emphasize early risk reduction with future scaled at-sea integrated demonstrations of increasing complexity. Program technologies will transition to the Navy. ***FY 2016 Accomplishments:*** - Evaluated environmental condition's impact on system performance via modeling and simulation. - Completed system architecture design trade studies and preliminary designs. - Continued fiber performance testing; demonstrated fiber survivability under at-sea conditions. - Conducted system-level performance modeling. - Completed component-level testing. - Commenced prototype system design and planning for future sea tests. ***FY 2017 Plans:*** - Complete and evaluate prototype system design and review. - Commence system fabrication and integration testing. - Continue at-sea system demonstration planning and coordination.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Demonstrate system architecture and information assurance in a shore-based hardware-in-the-loop simulation. ***FY 2018 Plans:*** - Complete prototype fabrication. - Demonstrate at-sea deployment, operation and connectivity. - Complete system integration testing. - Transition interface control and system architecture documentation to Navy. - Perform at-sea networking demonstration to facilitate 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 and culminate in a series of at-sea demonstrations and transition to the Navy. ***FY 2016 Accomplishments:*** - Completed component designs and design reviews. - Commenced module development and fabrication. - Commenced sub-system hardware and software testing and module integration. - Updated system performance models. - Commenced subsystem safety certifications and testing. ***FY 2017 Plans:*** - Complete module fabrication and integration. - Continue system at-sea testing. - Complete module and system safety and certification testing and analyses.	15.500	8.964	5.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Commence at-sea demonstration planning, training, and support preparations. - Complete system integration and checkouts. ***FY 2018 Plans:*** - Conduct at-sea demonstrations.			
Title: Positioning System for Deep Ocean Navigation (POSYDON)	23.865	26.970	23.718
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. Building upon concepts explored under the Distributed Agile Submarine Hunting (DASH) program, budgeted within this PE/Project, and the Upward Falling Payloads program, PE 0602702E, Project TT-03, 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 2016 Accomplishments:*** - Began design and development of algorithms for accurately predicting acoustic signal propagation paths. - Began development of the system concept of operations. - Commenced at-sea experiments to validate analysis using source/receiver pairs at basin-scale range to measure signal tracking accuracy and stability as well as signal acquisition techniques. ***FY 2017 Plans:*** - Complete at-sea experiments, data collection, and data analysis. - Design and develop signal waveforms for transmitters and receivers. - Refine the system concept of operations based on data collections from at-sea experiments. - Update ocean models to support real-time ranging. - Conduct multiple at-sea demonstrations of real-time ranging signals in various environments with noise and interference. ***FY 2018 Plans:*** - Complete development of user equipment. - Continue development of the acoustic propagation models and signal waveforms.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- 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.			
Title: Cross Domain Maritime Surveillance and Targeting (CDMaST)	5.785	17.558	29.669
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. Building upon research conducted under the System of Systems Integration Technology and Experimentation (SoSite) program (budgeted in PE 0603766E, Project NET-01), 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 2016 Accomplishments:*** - Established modeling and simulation environment to conduct high fidelity mission-level architecture analysis. - Developed baseline analysis scenario. ***FY 2017 Plans:*** - Develop initial system of systems architectures and initiate comprehensive architecture analysis. - Create preliminary design for system of systems live, virtual, and constructive test bed environment. - Create initial experimentation master plan. - Conduct initial Extra Large Unmanned Undersea Vehicle (XLUUV) payload delivery feasibility analysis. ***FY 2018 Plans:*** - Complete development of advanced architectures. - Finalize experimentation master plan. - Complete final design and initiate operation of the live, virtual and constructive test bed environment. - Initiate spiral experimentation and demonstration of the advanced CDMaST architecture. - Perform elemental and engineering tests on selected segments of the CDMaST architecture.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Perform operational tests leading to at-sea demonstrations of CDMaST capability to facilitate transition to the Navy. - Conduct Battle Management and Command and Control (BMC2) analysis to evaluate highly resilient kill chains.			
Title: Mobile Offboard Command, Control and Attack (MOCCA)	5.850	17.967	25.394
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 build on lessons learned under the Distributed Agile Submarine Hunting (DASH) program, budgeted within this PE/Project, to 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 2016 Accomplishments:*** - Developed conceptual design of hardware and software components. ***FY 2017 Plans:*** - Evaluate designs on compact acoustic projectors, and LPI/LPD communications link system components. - Develop subsystems for compact high output acoustic projector and LPI/LPD communications link system. - Commence 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 submarine Bi-static sonar processing algorithms. - Conduct feasibility and system design trade space studies. Identify UUV size, weight, and power requirements to accomplish mission. ***FY 2018 Plans:*** - Initiate process for approval of temporary system integration into submarine systems for test and evaluation. - Conduct system utility analysis to identify optimal performance specifications for concept of operations under multiple tactical situations. - Develop, evaluate, and select system designs for integrated active sonar and communication system on-board a UUV. - Perform systems integration for active sonar and communication systems into a test UUV platform. - Commence construction of integrated UUV sonar and communication system.			
Title: Hunter	-	-	15.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
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 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 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 and anti-tamper analysis of payload delivery system.			
Title: Tactical Exploitation of the Acoustic Channel (TEAC)	-	-	8.300
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. - Identify and develop mission concepts for TEAC technology.			
Title: Virtual Acoustic Microphone System (VAMS)	6.600	5.489	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Description: The Virtual Acoustic Microphone System (VAMS) program will develop additional acoustic sensor capabilities for underwater platforms. The VAMS program seeks to develop and demonstrate technologies that enable projection of underwater acoustic sensor arrays with performance comparable to existing arrays. The VAMS approach, however, will allow enabling capabilities that are not currently possible with existing technology. Expanding on lessons learned from the Distributed Agile Submarine Hunting (DASH) program, budgeted within this PE/Project, the program will combine novel transmitters with novel signal extraction methods and exploit new and emerging high-speed sensor and processor capabilities. The VAMS system has the potential to be integrated into a number of underwater platforms. The acoustic sensor technology developed under the VAMS program will transition to the Navy. ***FY 2016 Accomplishments:*** - Evaluated core enabling technologies, including the application of high-speed sensor technology to increase the sensitivity of acoustic detection. - Conducted a series of initial underwater phenomenology experiments to support system analysis and design. - Completed the demonstration of core enabling technologies and applied the results to the design of the initial demonstration system. ***FY 2017 Plans:*** - Complete system design.			
Title: Distributed Agile Submarine Hunting (DASH) ***Description:*** The diesel-electric submarine is an asymmetric threat in terms of its cost and consequential growth in numbers relative to our legacy maritime platforms. In addition, these submarines have trended toward lower acoustic signature levels and have grown in lethality. The Distributed Agile Submarine Hunting (DASH) program's goal was to reverse the asymmetric advantage of this threat through the development of advanced standoff sensing from unmanned systems. Deep-ocean sonar nodes were developed to operate at significant depths in open ocean areas to achieve large fields of view to detect submarines overhead. Each deep node is the maritime equivalent of a satellite, and is referred to as a subullite. The significant field of view, along with the advantage of low-noise phenomena at extreme depths, permitted a scalable number of collaborative sensor platforms to detect and track submarines over large areas. At-sea demonstrations revealed that the detection capability has been achieved. The program developed prototype systems that evolved through additional at-sea testing. These tests demonstrated the ability to integrate into the Navy's undersea systems responsible for anti-submarine warfare (ASW). The program achieved breakthrough technology for long-range detection and classification, communications, energy management, sensor and platform integration, and robust semiautonomous processing and control for distributed sensing platforms. DASH technologies have transitioned to the Navy.	9.780	-	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
FY 2016 Accomplishments: - Conducted at-sea demonstrations of a distributed deep-ocean passive sonar barrier using multiple nodes for extended duration. - Conducted at-sea demonstrations of a mobile active sonar node. - Performed data-driven signal processing development to improve automated sonar detection algorithms. - Provided analysis and data to support Navy utility assessments and studies to aid in transition. - Completed data collection experiments in other significant Navy operational areas to characterize DASH performance. - Continued to explore alternate techniques for long-range submarine detection and precision target tracking. - Conducted sea testing with the Navy in operationally relevant environments. - Participated in major fleet prototype operational experimentation and assessment of the DASH system supporting transition activities.			
Accomplishments/Planned Programs Subtotals	139.053	138.303	138.112

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	212.245	217.675	234.160	-	234.160	187.106	149.200	54.600	4.000	-	-

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 2016	FY 2017	FY 2018
Title: Classified DARPA Program	212.245	217.675	234.160
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2016 Accomplishments:*** Details will be provided under separate cover. ***FY 2017 Plans:*** Details will be provided under separate cover. ***FY 2018 Plans:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	212.245	217.675	234.160

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	231.633	241.288	210.123	-	210.123	177.278	281.085	301.554	286.554	-	-
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	19.772	19.027	37.843	-	37.843	32.694	26.901	18.401	11.401	-	-
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	129.858	145.732	107.813	-	107.813	103.709	230.684	272.653	267.153	-	-
SEN-03: *EXPLOITATION SYSTEMS*	-	9.456	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
SEN-06: *SENSOR TECHNOLOGY*	-	72.547	76.529	64.467	-	64.467	40.875	23.500	10.500	8.000	-	-

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.

The Exploitation Systems project developed algorithms, software, and information processing systems to extract information from massive Intelligence, Surveillance, and Reconnaissance (ISR) datasets. In particular, it developed new technologies for detection and discrimination of targets from clutter, classification and fingerprinting

of high value targets, localization and tracking over wide areas, and threat network identification and analysis. Interest extended to open source information and issues such as trustworthiness and provenance. The resulting technology enables operators to more effectively and efficiently incorporate all sources of information, including sensor, human, and open source data, in intelligence products.

B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	240.127	241.288	207.325	-	207.325
Current President's Budget	231.633	241.288	210.123	-	210.123
Total Adjustments	-8.494	0.000	2.798	-	2.798
• 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	0.277	0.000			
• SBIR/STTR Transfer	-8.771	0.000			
• TotalOtherAdjustments	-	-	2.798	-	2.798

Change Summary Explanation

FY 2016: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.

FY 2017: N/A

FY 2018: Increase reflects Blue Note program new start.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	19.772	19.027	37.843	-	37.843	32.694	26.901	18.401	11.401	-	-

A. Mission Description and Budget Item Justification

This 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 2016	FY 2017	FY 2018
Title: Multi-Optical Sensing (MOS)	19.772	15.027	15.960

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 control for fighter class and long-range strike aircraft. This program leverages emerging high-sensitivity focal plane array (FPA) and compact, multiband 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, multiband, 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 Services.

FY 2016 Accomplishments:
- Completed the development of the first-generation prototype system.
- Performed air-to-air demonstrations with the first-generation prototype system.
- Initiated the development of a second-generation prototype system, which will demonstrate the full capability out to operational ranges.

FY 2017 Plans:
- Complete the development of the second-generation prototype system and integrate onto an airborne platform.
- Perform air-to-air demonstrations with the second-generation prototype system.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Perform initial demonstration of the full capability of the second-generation prototype system out to operational ranges. ***FY 2018 Plans:*** - Conduct demonstration of all modalities of second-generation prototype system capability out to operational ranges. - Incorporate target measurement data into identification algorithms and demonstrate multi-modality identification out to operational ranges. - Demonstrate system scalability through design and analysis to the size, weight, and power necessary for an objective implementation. - Develop roadmap and injection point for transition of capability into near-term and far-term Air Force and Navy operational systems.			
Title: Aerial Dragnet ***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 technologies developed 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-wide 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 2017 Plans:*** - Commence development of surveillance subsystems for UAS detection, classification, and localization from an aerial platform. - Conduct engineering subsystem tests to assess small UAS detection performance in an instrumented urban test area. ***FY 2018 Plans:*** - Complete development of initial hardware sensor payloads. - Evaluate software for non-line-of-sight UAS tracking and classification. - Demonstrate and test the performance of the system over a neighborhood-sized urban area.	-	4.000	14.383
Title: Blue Note	-	-	7.500

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
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. - Begin design of new jamming waveforms. - Conduct initial data collection using existing U.S. radars.			
Accomplishments/Planned Programs Subtotals	19.772	19.027	37.843

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	129.858	145.732	107.813	-	107.813	103.709	230.684	272.653	267.153	-	-

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 2016	FY 2017	FY 2018
Title: Spatial, Temporal and Orientation Information for Contested Environments (STOIC)	26.900	21.365	15.632

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 2016 Accomplishments:
- Completed prototype components of optical clocks.
- Completed detailed design and began development of compact optical clocks.
- Developed prototype components and systems for enabling precision time transfer independent of GPS.
- Completed detailed design and began development of GPS-independent precision time transfer systems.
- Developed prototype jam-proof Positioning, Navigation, and Timing (PNT) system components (signal transmit and receive) for achieving GPS-level positioning performance in contested environments.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Completed detailed design and began development of jam-proof PNT system based on very low frequency (VLF) transmitters and waveforms. ***FY 2017 Plans:*** - Complete development of compact optical clocks. - Complete initial demonstration of prototype GPS-independent precision time transfer system and begin system evaluations. - Complete development of jam-proof PNT system and conduct tests to validate system performance. ***FY 2018 Plans:*** - Conduct real-time demonstrations of jam-proof VLF-based positioning system. - Complete validation of optical clock long-term performance. - Conduct real-time demonstration of precision time transfer using tactical data link signals. - Leverage real-time demonstrations on relevant platforms to facilitate transition discussions with the Navy and Air Force.			
Title: Automatic Target Recognition (ATR) Technology	16.259	24.759	18.652
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 2016 Accomplishments:*** - Initiated design of an embedded real-time, low-cost radar ATR processor that incorporates advanced ATR algorithms and uses commercial mobile embedded computing platforms. - Designed and executed additional data collection experiments for continued algorithm development and testing. - Continued to improve ATR algorithm performance, including decoy rejection and false target rejection. - Initiated design of an Open Mission System (OMS) architecture study for ATR algorithms to enable rapid and flexible integration onto multiple operational platforms.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Evaluated first set of results from ATR algorithms, with results matching or exceeding comparable state-of-the-art algorithms. ***FY 2017 Plans:*** - Develop adaptable ATR algorithms to rapidly learn new targets with minimal measured data and evaluate algorithm learning rate. - Evaluate algorithm performance against denied targets for which limited or no training data is available. - Conduct radar data collection to provide additional targets and training data. - Continue to improve ATR algorithm performance, focusing on false-alarm performance. - Complete design and begin development of a flightworthy, low-power ATR processing hardware that executes the ATR algorithm in real-time. - Demonstrate ATR algorithm running in an OMS enabled environment on embedded hardware. ***FY 2018 Plans:*** - Continue to improve ATR algorithm performance, focusing on reducing processing times and system size and power requirements. - Continue development of a flightworthy, low-power ATR processing hardware that executes the ATR algorithm in real-time. - Prepare for a flight demonstration of ATR algorithms running on an airborne platform. - Perform flight demonstration of ATR algorithms operating on an airborne platform to facilitate transition to the Services.			
Title: Seeker Cost Transformation (SECTR) ***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 2016 Accomplishments:*** - Initiated development of core seeker system engineering design.	13.315	20.002	15.989

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Initiated development of open seeker standard architecture and interfaces. - Developed small size, weight, and power (SWaP) and cost sensor and processing unit. - Designed novel target recognition algorithms. - Designed GPS-free image navigation and processing sensor and algorithm. - Performed initial hardware-in-the-loop (HWIL) test for GPS-free navigation algorithms. - Performed initial HWIL test for target recognition algorithms. ***FY 2017 Plans:*** - Conduct laboratory demonstrations of sensor/processing unit. - Conduct captive flight test of small SWaP sensors. - Complete Critical Design Review (CDR) of the prototype seeker system. - Integrate GPS-free navigation software and target recognition software into the small SWaP sensors/processing unit. - Conduct HWIL test of integrated sensors/processing unit with GPS-free navigation and target recognition software. - Complete and distribute seeker open standard architecture and interfaces. ***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 HWIL tests simulating flight with integrated PGM platforms. - Conduct flight test of integrated prototype SECTR seeker-guided PGM.			
Title: Small Satellite Sensors	8.000	24.478	29.651
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 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.			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
FY 2016 Accomplishments: - Developed conceptual designs for EO/IR sensor and inter-satellite communications link subsystems. - Developed software performance models for candidate sensor systems, and performed laboratory testing to improve model fidelity and assist in design of flight hardware. - Began design of experimental sensor payloads compatible with a small satellite bus, and performed preliminary design review. - Began development of lightweight and low-power inter-satellite communications links suitable for providing high-bandwidth crosslinks for 100 pound class satellites. - Investigated alternative low-cost payloads suitable for integration on a small satellite. ***FY 2017 Plans:*** - Complete detailed design of small satellite EO/IR sensor, and complete satellite system critical design review. - Complete construction of the first small EO/IR payload and satellite bus. - Build inter-satellite communications link hardware for integration into satellites. - Develop and test mission data processing software. - Develop detailed plan for on-orbit operations. - Initiate design of direct-to-user data downlinks for tactical experimentation with time-critical strike concepts. ***FY 2018 Plans:*** - Launch one or more satellites into low earth orbit, each with a compact telescope and an EO/IR sensor. - Initiate on-orbit operations including mission planning, payload testing, and image collection. - Demonstrate on-board image processing. - Downlink raw imagery for ground processing and pre-processed imagery for comparative analysis. - Use the results from data collections to determine the appropriate attributes of an objective system. - Implement direct-to-user data link hardware and software on at least one satellite. - Develop ground-segment receivers and experimentation plan for real-time demonstrations.			
Title: Adaptive Radar Countermeasures (ARC)	20.512	19.487	4.200
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			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
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 2016 Accomplishments:*** - Completed real-time software and firmware implementation of all major algorithm modules on transition partner provided baseline electronic warfare (EW) systems. - Refined adaptive radar threat models for use in testing which emulate future adversary radar capabilities that are expected to challenge current baseline EW systems. - Demonstrated real-time prototype systems by effectively operating against unanticipated or ambiguous radar signals in a hardware-in-the-loop laboratory environment. ***FY 2017 Plans:*** - Identify test ranges and assets that emulate advanced, complex radar signals in static and open-air testing environments. - Develop detailed flight demonstration objectives and conduct test readiness reviews in coordination with Service transition partners. - Refine algorithms to make them robust to realistic Radio Frequency (RF) test conditions in real-time laboratory testing, free-space static testing, and open-air flight demonstrations. ***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.			
Title: Dynamically Composed RF Systems ***Description:*** Dominance of the 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. Expanding on ideas developed under the Multifunction RF program, also budgeted in this PE/ Project, 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 (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.	-	14.000	23.689

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
FY 2017 Plans: - Assemble requirements to provide an abstraction of underlying software and hardware architectures (RF Virtual Machine). - Commence design of modular architecture for agile, collaborative converged RF payload systems, and assessment of candidate missions, platforms, and costs. - Commence design of RF apertures and associated airframe integration, and agile low-power wide-band RF electronics suitable for RF payloads for compact platforms/UAVs. - Commence development of SSRM software for controlling and scheduling RF hardware (including processor) to carry out the desired RF functions. - Explore and experimentally establish technical readiness of candidate design approaches to technical program elements. ***FY 2018 Plans:*** - Demonstrate intelligent 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 / UAVs. - Design and begin implementation of SSRM software to control and schedule the RF hardware to execute converged RF missions with functional and spectral flexibility.			
Title: Advanced Scanning Technology for Imaging Radars (ASTIR)	12.988	10.985	-
Description: The Advanced Scanning Technology for Imaging Radars (ASTIR) program will provide immediate benefit to applications that are constrained by power, weight, and the complexity limits of production. The goal of this program, building on technologies developed under the Multifunction RF (MFRF) program which is budgeted in this PE/Project, is 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 will: (1) provide high-resolution 3D imaging for enhanced identification and targeting, independent of platform or target motion; (2) produce 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) integrate millimeter-wave (mmW)/terahertz (THz) electronic component advancements from other DARPA programs for transmit and receive functions. The completion of this program will result in a more readily available, cost-effective imaging radar technology that will work in concert with a wide area surveillance system to provide target identification at video frame rates in all conditions where existing sensors will not work. Candidate military applications include efficient terminal seekers, imaging systems for defense of shipping in ports and littoral environments,			

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
base perimeter monitoring, and screening of personnel passing through access control points. This technology is intended to transition to Special Operations Command and the Navy. ***FY 2016 Accomplishments:*** - Developed sensor design concepts and defined processing requirements. - Built prototype electronic sub-reflector beam-steering systems and conducted tests to characterize performance and validate approach. - Conducted mission studies and determined the system performance metrics required to support specific candidate military applications. ***FY 2017 Plans:*** - Complete assessments of candidate military applications and show benefit from technologies developed under this effort. - Complete electronically scanned sub-reflector sensor requirements. - Design imaging radar system utilizing technologies developed under this effort to address additional military applications.			
Title: Multifunction RF (MFRF) ***Description:*** The Multifunction RF (MFRF) program goal is to enable U.S. rotary wing aircraft forces to fight effectively in all forms of severely Degraded Visual Environments (DVE) when our adversaries cannot. The program goes 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 seeks 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 will reduce 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 includes: (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. The program is planned for transition to the Army. ***FY 2016 Accomplishments:*** - Conducted laboratory and field demonstrations with integrated ARMS, synthetic vision backbone, other potential collision avoidance sensors and multifunction software development kit.	7.273	3.500	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
- Demonstrated DVE landing, takeoff, Ground Moving Target Indicator (GMTI), and Synthetic Aperture Radar (SAR) modes of operation. ***FY 2017 Plans:*** - Prepare technologies developed under MFRF for planned transition to the Army.			
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 seeks to 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 planned to transition to Air Force Special Operations Command (AFSOC). ***FY 2016 Accomplishments:*** - Completed development and unit-level testing of flightworthy high power amplifier. - Integrated hardware into a sensor control system (gimbal) and demonstrated performance in a laboratory scenario, and in over-the-air testing against calibration targets. - Integrated hardware and gimbal on a surrogate aircraft. - Conducted flight tests to demonstrate ViSAR performance in comparison to Electro-Optic sensors. ***FY 2017 Plans:*** - Conduct flight demonstrations in cooperation with the Air Force Research Laboratory (AFRL) and AFSOC.	12.250	4.500	-
Title: Military Imaging and Surveillance Technology (MIST) ***Description:*** The Military Imaging and Surveillance Technology (MIST) program is developing a fundamentally new optical Intelligence, Surveillance, and Reconnaissance (ISR) capability that provides high-resolution 3-D images to locate and identify a target at much longer ranges than is possible with existing optical systems. Short, moderate, and long-range prototype optical surveillance and observation systems are being developed that: (1) demonstrate probabilities of recognition and identification at distances sufficient to allow stand-off engagement; (2) overcome atmospheric turbulence, which now limits the ability of high-resolution optics; and (3) increase target identification confidence to reduce fratricide and/or collateral damage. The program will develop and integrate the necessary component technologies including high-energy pulsed lasers, receiver telescopes that have a field of view and depth of field that obviates the need for steering or focusing the optical system, computational imaging algorithms	12.361	2.656	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
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 2016	FY 2017	FY 2018
to improve system resolution, and data exploitation and analysis tools. Advances in laser systems, digital imagers, and novel image processing algorithms will be leveraged to reduce the overall size, weight, and power (SWaP) of imaging systems to allow for soldier portable and Unmanned Aerial Vehicle (UAV) platform integration. The MIST program will transition the optical ISR technology to the Services and Special Operations Command (SOCOM). ***FY 2016 Accomplishments:*** - Completed the development of the short-range 3-D imaging system. - Demonstrated the capabilities of the completed short-range 3-D imaging system. - Completed the development of the mountain-to-ground demonstration capability for the moderate-range 3-D imaging system. - Conducted mountain-to-ground demonstrations of the moderate-range 3-D imaging system. ***FY 2017 Plans:*** - Transition the short-range and moderate-range 3-D imaging system to the Services and SOCOM.			
Accomplishments/Planned Programs Subtotals	129.858	145.732	107.813

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603767E / *SENSOR TECHNOLOGY*	Project (Number/Name) SEN-03 / *EXPLOITATION SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
SEN-03: *EXPLOITATION SYSTEMS*	-	9.456	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Exploitation Systems project developed algorithms, software, and information processing systems to extract information from massive Intelligence, Surveillance, and Reconnaissance (ISR) datasets. In particular, it developed new technologies for detection and discrimination of targets from clutter, classification and fingerprinting of high value targets, localization and tracking over wide areas, and threat network identification and analysis. Interest extended to open source information and issues such as trustworthiness and provenance. The resulting technology enables operators to more effectively and efficiently incorporate all sources of information, including sensor, human, and open source data, in intelligence products.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Insight	9.456	-	-

Description: Insight developed the next generation multi-intelligence exploitation and analysis system. Insight provided new exploitation capabilities through an integrated, standards-based system that is designed for mission flexibility and cross-theater applicability. Insight enabled threat detection through combination and analysis of information from imaging and non-imaging sensors and other sources. The technical approach emphasized graph-based correlation, adversary behavior modeling, threat network analysis tools, a unified data management and processing environment, novel exploitation algorithms and analysis methodologies, and tools to integrate human and machine processing, including visualization, hypothesis manipulation, and on-line learning. Insight development activities leveraged both virtual and physical test bed environments. The virtual test bed enabled evaluation of alternative sensor mixes and algorithms under extended operating conditions. The physical test bed enabled live testing under realistic operational conditions using current and next generation sensing and processing systems. Insight technology development was coordinated with the following transition sponsors: Army Program Executive Office - Intelligence, Electronic Warfare & Sensors (PEO IE&WS), United States Army Intelligence Center of Excellence (USAICoE), Project Manager Distributed Common Ground System - Army (PM DCGS-A), Air Staff, National Air and Space Intelligence Center (NASIC), Air Force Research Laboratory, and an operational command partner. There are MOAs or MOUs in place with each of these transition stakeholders. Insight provided a unified architecture for plug-and-play ISR with extensibility to all Services and Combatant Commands.

FY 2016 Accomplishments:

- Tested advanced fusion and analytic technologies, and demonstrated improvements and maturity of multi-intelligence exploitation capabilities.
- Addressed capability objectives and key performance parameters identified by the Army, and delivered Insight software to PM DCGS-A.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Defense Advanced Research Projects Agency		Date: May 2017
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-03 / *EXPLOITATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
- Met capability objectives jointly identified with NASIC, delivered Insight software to NASIC, and conducted assessments of the capabilities in conjunction with NASIC personnel. - Provided a capability to support operational command partner exercises and mission training, delivered Insight software to the partner, and collaborated on the application of Insight capabilities to partner training exercises.			
Accomplishments/Planned Programs Subtotals	9.456	-	-

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: FY 2018 Defense Advanced Research Projects Agency			Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
SEN-06: *SENSOR TECHNOLOGY*	-	72.547	76.529	64.467	-	64.467	40.875	23.500	10.500	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 2016	FY 2017	FY 2018
Title: Classified DARPA Program	72.547	76.529	64.467
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2016 Accomplishments:*** Details will be provided under separate cover. ***FY 2017 Plans:*** Details will be provided under separate cover. ***FY 2018 Plans:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	72.547	76.529	64.467

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	0.000	69.244	63.769	-	63.769	66.051	66.560	66.453	67.431	-	-
MST-01: *MISSION SUPPORT*	-	0.000	69.244	63.769	-	63.769	66.051	66.560	66.453	67.431	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

This program element is budgeted in the Management Support Budget Activity as it 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. Mission support administrative costs were previously budgeted in PE 0605898E, Project MH-01.

B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	0.000	69.244	71.293	-	71.293
Current President's Budget	0.000	69.244	63.769	-	63.769
Total Adjustments	0.000	0.000	-7.524	-	-7.524
• 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	-	-	-7.524	-	-7.524

Change Summary Explanation

FY 2016: N/A

FY 2017: N/A

FY 2018: Decrease reflects funding realignment to Management Headquarters - R&D for Management Headquarters Activities (MHA) service support contracts and civilian personnel repricing.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Mission Support	-	69.244	63.769
Description: Mission Support			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
FY 2017 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 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.			
Accomplishments/Planned Programs Subtotals	-	69.244	63.769

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	89.060	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
SB-01: *SMALL BUSINESS INNOVATION RESEARCH*	-	89.060	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: 114-92 (National Defense Authorization Act 2016) 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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	0.000	0.000	0.000	-	0.000
Current President's Budget	89.060	0.000	0.000	-	0.000
Total Adjustments	89.060	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	89.060	0.000			

Change Summary Explanation

FY 2016: Increase reflects the SBIR/STTR transfer.
FY 2017: N/A
FY 2018: N/A

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Small Business Innovation Research	89.060	-	-
Description: The 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			

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
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. ***FY 2016 Accomplishments:*** - The DARPA SBIR and STTR were executed within OSD guidelines.			
Accomplishments/Planned Programs Subtotals	89.060	-	-

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: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	-	71.571	4.759	14.017	-	14.017	13.493	13.339	13.420	13.497	-	-
MH-01: *MANAGEMENT HQ - R&D*	-	71.571	4.759	14.017	-	14.017	13.493	13.339	13.420	13.497	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

This program element is budgeted in the Management Support Budget Activity as it provides funding for the administrative support costs of the Defense Advanced Research Projects Agency. In FY 2016, the PE funds personnel compensation for civilians as well as costs for building rent, physical security, travel, supplies and equipment, communications, printing and reproduction. Beginning in FY 2017, this project provides funding for the Management Headquarters Activities (MHA) of DARPA only. The funds provide personnel compensation for management headquarters civilians as well as associated travel and support contract costs. Departmental Service Requirements Review Board (SRRB) reductions were taken in the PE. Mission support costs are reflected in PE 0605001E, Project MST-01.

B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	71.571	4.759	4.835	-	4.835
Current President's Budget	71.571	4.759	14.017	-	14.017
Total Adjustments	0.000	0.000	9.182	-	9.182
• 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	-	-	9.182	-	9.182

Change Summary Explanation

FY 2016: N/A

FY 2017: N/A

FY 2018: Increase reflects funding realignment from Mission Support for Management Headquarters Activities (MHA) service support contracts and civilian personnel repricing.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Management Headquarters	71.571	4.759	14.017

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Defense Advanced Research Projects Agency	Date: May 2017
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 2016	FY 2017	FY 2018
Description: Management Headquarters ***FY 2016 Accomplishments:*** - Funded civilian salaries and benefits, and administrative support costs. - Funded travel, rent and other infrastructure support costs. - Funded security costs to continue access controls, uniformed guards, and building security requirements. - Funded CFO Act compliance costs. ***FY 2017 Plans:*** - Fund management headquarters civilian salaries, benefits, and travel costs. ***FY 2018 Plans:*** - Fund management headquarters civilian salaries, benefits, travel and support contract costs.			
Accomplishments/Planned Programs Subtotals	71.571	4.759	14.017

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.