Department of Defense
Fiscal Year (FY) 2017 President's Budget Submission

February 2016

Defense Advanced Research Projects Agency

Defense-Wide Justification Book Volume 1 of 1

Research, Development, Test & Evaluation, Defense-Wide

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Table of Volumes

Volume 1 Table of Contents

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Department of Defense
FY 2017 President's Budget
Exhibit R-1 FY 2017 President's Budget
Total Obligational Authority
(Dollars in Thousands)

08 Jan 2016

Appropriation	FY 2015 (Base & OCO)	FY 2016 Base Enacted	FY 2016 OCO Enacted	FY 2016 Total Enacted	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Research, Development, Test & Eval, DW	2,915,932	2,868,281		2,868,281	2,973,036		2,973,036
Total Research, Development, Test & Evaluation	2,915,932	2,868,281		2,868,281	2,973,036		2,973,036

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08 Jan 2016

Summary Recap of Budget Activities	FY 2015 (Base & OCO)	FY 2016 Base Enacted	FY 2016 OCO Enacted	FY 2016 Total Enacted	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Basic Research	381,371	389,663		389,663	420,088		420,088
Applied Research	1,136,845	1,163,380		1,163,380	1,246,308		1,246,308
Advanced Technology Development	1,241,088	1,243,667		1,243,667	1,232,637		1,232,637
Management Support	156,628	71,571		71,571	74,003		74,003
Total Research, Development, Test & Evaluation	2,915,932	2,868,281		2,868,281	2,973,036		2,973,036

Summary Recap of FYDP Programs	FY 2015 (Base & OCO)	FY 2016 Base Enacted	FY 2016 OCO Enacted	FY 2016 Total Enacted	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Research and Development	2,915,932	2,868,281		2,868,281	2,973,036		2,973,036
Total Research, Development, Test & Evaluation	2,915,932	2,868,281		2,868,281	2,973,036		2,973,036

Defense-Wide
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Summary Recap of FYDP Programs							
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R-1C1: FY 2017 President's Budget (Published Version of PB Position), as of January 8, 2016 at 09:33:10

Defense-Wide
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08 Jan 2016

Appropriation	FY 2015 (Base & OCO)	FY 2016 Base Enacted	FY 2016 OCO Enacted	FY 2016 Total Enacted	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Defense Advanced Research Projects Agency	2,915,932	2,868,281		2,868,281	2,973,036		2,973,036
Total Research, Development, Test & Evaluation	2,915,932	2,868,281		2,868,281	2,973,036		2,973,036

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Defense-Wide
FY 2017 President's Budget
Exhibit R-1 FY 2017 President's Budget
Total Obligational Authority
(Dollars in Thousands)

08 Jan 2016

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

Line No	Program Element Number	Item	Act	FY 2015 (Base & OCO)	FY 2016 Base Enacted	FY 2016 OCO Enacted	FY 2016 Total Enacted	FY 2017 Base	FY 2017 OCO	FY 2017 Total	Sec
2	0601101E	Defense Research Sciences	01	322,030	333,119		333,119	362,297		362,297	U
4	0601117E	Basic Operational Medical Research Science	01	59,341	56,544		56,544	57,791		57,791	U
		Basic Research		381,371	389,663		389,663	420,088		420,088	
9	0602115E	Biomedical Technology	02	164,589	114,262		114,262	115,213		115,213	U
13	0602303E	Information & Communications Technology	02	315,923	341,358		341,358	353,635		353,635	U
14	0602383E	Biological Warfare Defense	02	42,447	24,265		24,265	21,250		21,250	U
17	0602702E	Tactical Technology	02	299,787	302,582		302,582	313,843		313,843	U
18	0602715E	Materials and Biological Technology	02	144,409	206,115		206,115	220,456		220,456	U
19	0602716E	Electronics Technology	02	169,690	174,798		174,798	221,911		221,911	U
		Applied Research		1,136,845	1,163,380		1,163,380	1,246,308		1,246,308	
36	0603286E	Advanced Aerospace Systems	03	123,292	173,631		173,631	182,327		182,327	U
37	0603287E	Space Programs and Technology	03	172,504	126,692		126,692	175,240		175,240	U
55	0603739E	Advanced Electronics Technologies	03	81,119	76,021		76,021	49,807		49,807	U
56	0603760E	Command, Control and Communications Systems	03	229,945	201,335		201,335	155,081		155,081	U
57	0603766E	Network-Centric Warfare Technology	03	350,323	425,861		425,861	428,894		428,894	U
58	0603767E	Sensor Technology	03	283,905	240,127		240,127	241,288		241,288	U
		Advanced Technology Development		1,241,088	1,243,667		1,243,667	1,232,637		1,232,637	
138	0605001E	Mission Support	06					69,244		69,244	U
154	0605502E	Small Business Innovative Research	06	85,266							U

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Line No	Program Element Number	Item	Act	FY 2015 (Base & OCO)	FY 2016 Base Enacted	FY 2016 OCO Enacted	FY 2016 Total Enacted	FY 2017 Base	FY 2017 OCO	FY 2017 Total	Sec
163	0605898E	Management HQ - R&D	06	71,362	71,571		71,571	4,759		4,759	U
		Management Support		156,628	71,571		71,571	74,003		74,003	
		Total Research, Development, Test & Eval, DW		2,915,932	2,868,281		2,868,281	2,973,036		2,973,036	

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		Basic Research		381,371	389,663		389,663	420,088		420,088	
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13	0602303E	Information & Communications Technology	02	315,923	341,358		341,358	353,635		353,635	U
14	0602383E	Biological Warfare Defense	02	42,447	24,265		24,265	21,250		21,250	U
17	0602702E	Tactical Technology	02	299,787	302,582		302,582	313,843		313,843	U
18	0602715E	Materials and Biological Technology	02	144,409	206,115		206,115	220,456		220,456	U
19	0602716E	Electronics Technology	02	169,690	174,798		174,798	221,911		221,911	U
		Applied Research		1,136,845	1,163,380		1,163,380	1,246,308		1,246,308	
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55	0603739E	Advanced Electronics Technologies	03	81,119	76,021		76,021	49,807		49,807	U
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Line No	Program Element Number	Item	Act	FY 2015 (Base & OCO)	FY 2016 Base Enacted	FY 2016 OCO Enacted	FY 2016 Total Enacted	FY 2017 Base	FY 2017 OCO	FY 2017 Total	Sec
		Management Support		156,628	71,571		71,571	74,003		74,003	
		Total Defense Advanced Research Projects Agency		2,915,932	2,868,281		2,868,281	2,973,036		2,973,036	

R-1C1: FY 2017 President's Budget (Published Version of PB Position), as of January 8, 2016 at 09:33:10

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

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

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

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

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: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	322.030	333.119	362.297	-	362.297	361.151	365.461	372.674	376.113	-	-
BLS-01: *BIO/INFO/MICRO SCIENCES*	-	14.000	6.127	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
CCS-02: *MATH AND COMPUTER SCIENCES*	-	111.223	144.290	149.065	-	149.065	158.762	165.583	163.036	167.036	-	-
CYS-01: *CYBER SCIENCES*	-	48.178	50.428	45.000	-	45.000	47.219	27.000	10.000	10.000	-	-
ES-01: *ELECTRONIC SCIENCES*	-	39.947	40.824	49.553	-	49.553	38.151	40.996	44.883	44.883	-	-
MS-01: *MATERIALS SCIENCES*	-	77.942	53.060	65.609	-	65.609	60.387	63.780	85.138	85.138	-	-
TRS-01: *TRANSFORMATIVE SCIENCES*	-	30.740	38.390	53.070	-	53.070	56.632	68.102	69.617	69.056	-	-

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 will explore and develop potential technological breakthroughs that exist at the intersection of biology, information technology and micro/physical systems to exploit advances and leverage fundamental discoveries for the development of new technologies, techniques and systems of interest to the DoD. Programs in this project will draw upon 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.

The Math and Computer Sciences project supports long term national security requirements through scientific research and experimentation in new computational models and mechanisms for reasoning and communication in complex, interconnected systems. The project is exploring novel means of leveraging computer capabilities, including: practical, logical, heuristic, and automated reasoning by machines; development of 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.

The Cyber Sciences project supports long term national security requirements through scientific research and experimentation in cybersecurity. Networked computing systems control virtually everything, from power plants and energy distribution, transportation systems, food and water distribution, financial systems, to defense

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601101E I *DEFENSE RESEARCH SCIENCES*

systems. Protecting the infrastructure on which these systems rely is a national security issue. The Cyber Sciences project will ensure DoD cyber-capabilities survive adversary attempts to degrade, disrupt, or deny military computing, communications, and networking systems. Basic research in cyber security is required to provide a basis for continuing progress in this area. Promising research results will transition to both technology development and system-level projects.

The Electronic Sciences project explores and demonstrates electronic and optoelectronic devices, circuits and processing concepts that will provide: 1) new technical options for meeting the information gathering, transmission and processing required to maintain near-real time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near-real time; and 2) provide new means for achieving substantial increases in performance and cost reduction of military systems providing these capabilities.

The Materials Sciences project provides the fundamental research that underpins the development and assembly of advanced nanoscale and bio-molecular materials, devices, and electronics for DoD applications that greatly enhance soldier awareness, capability, security, and survivability, such as materials with increased strength-to-weight ratio and ultra-low size, devices with ultra-low energy dissipation and power, novel spectroscopic sources, and electronics with persistent intelligence and improved surveillance capabilities.

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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	332.146	333.119	328.362	-	328.362
Current President's Budget	322.030	333.119	362.297	-	362.297
Total Adjustments	-10.116	0.000	33.935	-	33.935
• 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	-10.116	0.000			
• TotalOtherAdjustments	-	-	33.935	-	33.935

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2015	FY 2016
Project: CCS-02: *MATH AND COMPUTER SCIENCES*		
Congressional Add: *Basic Research Congressional Add*	3.334	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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*

Congressional Add Details ($ in Millions, and Includes General Reductions)	**FY 2015**	**FY 2016**
Congressional Add Subtotals for Project: CCS-02	3.334	-
Project: CYS-01: *CYBER SCIENCES*		
Congressional Add: *Basic Research Congressional Add*	3.334	-
Congressional Add Subtotals for Project: CYS-01	3.334	-
Project: ES-01: *ELECTRONIC SCIENCES*		
Congressional Add: *Basic Research Congressional Add*	6.666	-
Congressional Add Subtotals for Project: ES-01	6.666	-
Project: MS-01: *MATERIALS SCIENCES*		
Congressional Add: *Basic Research Congressional Add*	6.666	-
Congressional Add Subtotals for Project: MS-01	6.666	-
Congressional Add Totals for all Projects	20.000	-

Change Summary Explanation

FY 2015: Decrease reflects the SBIR/STTR transfer.
FY 2016: N/A
FY 2017: Increase reflects expanded focus in Math and Computer sciences, Electronics, Materials and Transformative sciences.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
BLS-01: *BIO/INFO/MICRO SCIENCES*	-	14.000	6.127	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

This project is investigating and developing 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 will draw 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 will develop 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 2015	FY 2016	FY 2017
Title: Quantitative Models of the Brain	9.600	6.127	-
Description: The Quantitative Models of the Brain program will establish 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 will be 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 will develop powerful new symbolic computational capabilities for the DoD in a mathematical system that will provide the ability to understand complex and evolving signals and tasks while decreasing software and hardware requirements and other measurement resources. This includes 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 will enable these advances. This program will further exploit advances in the understanding and modeling of brain activity and organization to improve training of individuals and teams as well as identify new therapies for cognitive rehabilitation (e.g., Traumatic Brain Injury (TBI), Post Traumatic Stress Disorder (PTSD)). Critical to success will be 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 2015 Accomplishments: - Quantified spatio-temporal patterns of neurophysiological activity underlying memory formation. - Extended models and brain regions to account for hierarchical organization of memories (procedural, declarative/episodic). - Demonstrated model prediction of knowledge and skill-based memory encoding. - Developed model of memory encoding using non-invasively recorded neural signals.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Developed sparse multiple input/multiple output nonlinear dynamical modeling methodology for real-time application to electrophysiological recordings. ***FY 2016 Plans:*** - Build hippocampal-neocortical model of stimulation-based memory enhancement. - Develop and apply a new set of classification models for the prediction of behavioral outcomes from the spatio-temporal patterns of electrophysiological recordings in the hippocampus. - Develop initial computational model of integrated neural, physiological, and environmental effects in neural replay, skill acquisition, and subsequent memory recall.			
Title: Bio Interfaces ***Description:*** The Bio Interfaces program supported scientific study and experimentation, emphasizing the interfaces between biology and the physical and mathematical/computer sciences. This unique interaction developed new mathematical and experimental tools for understanding biology in a way that allowed its application to a myriad of DoD problems. These tools will help exploit advances in the complex modeling of physical and biological phenomena. It is also expected that understanding the fundamentals of biology will aid in developing tools to understand complex, non-linear networks. This program also explored the fundamental nature of time in biology and medicine. This included mapping basic clock circuitry in biological systems from the molecular level up through unique species level activities with a special emphasis on the applicability to human biology. ***FY 2015 Accomplishments:*** - Investigated alternative strategies for treating disease by targeting clocking systems that drive temporal processes such as cell cycle progression and metabolic cycles. - Leveraged temporally collected data to test the impact of time on drug efficacy. - Discovered and tested novel compounds that target oscillatory networks to modulate neurodegenerative disease in an animal model.	4.400	-	-
Accomplishments/Planned Programs Subtotals	14.000	6.127	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

E. Performance Metrics

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

Exhibit R-2A, **RDT&E Project Justification:** PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016

Appropriation/Budget Activity	**R-1 Program Element (Number/Name)**	**Project (Number/Name)**
0400 / 1	PE 0601101E / *DEFENSE RESEARCH SCIENCES*	CCS-02 / *MATH AND COMPUTER SCIENCES*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
CCS-02: *MATH AND COMPUTER SCIENCES*	-	111.223	144.290	149.065	-	149.065	158.762	165.583	163.036	167.036	-	-

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 2015**	**FY 2016**	**FY 2017**
Title: Big Mechanism	15.000	23.100	25.000

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, open-source intelligence, and economic indications and warning.

FY 2015 Accomplishments:
- Developed model management techniques for storing, manipulating, and reasoning about tens of thousands of alternative causal models.
- Developed techniques to generate plausible causal hypotheses that can be tested in the lab.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Developed tools for operator drill-down, ambiguity clarification, and inconsistency reconciliation. - Demonstrated an initial capability to read thousands of published papers on various aspects of the Ras cancer pathway; extract the specifics of the results (e.g., Ras model fragments) being reported in each paper; and assemble Ras model fragments into a larger consolidated model of Ras biochemical interactions. ***FY 2016 Plans:*** - Demonstrate automated testing of machine-generated hypotheses. - Create new modes for visualizing and exploring models of huge scope that in their entirety exceed human cognitive capabilities. - Develop causal models that relate phenotype to genotype using biological big data. - Formulate statistical approaches for uncovering causal relationships in numerical data/time series and categorical data/symbol sequences. - Demonstrate prototype technologies in production mode by identifying drug targets and drugs for one or more specific classes of cancer. - Develop algorithms for early indications and/or tracking of medical conditions such as neurological impairment, musculoskeletal injury, and cardio-vascular issues. ***FY 2017 Plans:*** - Create interfaces and tools to support a public 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. - Explore the portability of Big Mechanism technologies to other domains. - Explore the application of genotype-phenotype models to biomanufacturing. - Develop and implement scalable algorithms that reveal causality networks in large, complex, heterogeneous datasets.			
Title: Building Resource Adaptive Software from Specifications (BRASS) ***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	5.996	15.500	20.919

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
resource-based specifications, and implement compiler and runtime transformations that can efficiently adapt to resource changes. ***FY 2015 Accomplishments:*** - Developed a preliminary evaluation framework to enable assessment of adaptation strategies for software systems in the face of resource changes. - Identified promising technical approaches to automatically discover and monitor resource changes. ***FY 2016 Plans:*** - Integrate specifications within an operational environment to monitor resource changes and trigger signals when resource invariants are violated. - Develop compile-time and runtime transformations that ensure survivable operation in the face of unexpected environment changes. - Build validation tools that certify that transformed applications satisfy specification assumptions in the context of new operating environment guarantees. - Develop platform-specific challenge problems from different 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 new compiler and runtime infrastructure that are sensitive to ecosystem evolution. - Incorporate lightweight monitoring tools capable of runtime verification of adaptive program transformations. - Evaluate the effectiveness of the developed systems in collaboration with potential transition partners.			
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 methods 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 2015 Accomplishments:*** - Initiated development of new dimensional reduction and surrogate model methods with theoretical error bounds for rigorous uncertainty analysis of large-scale, coupled systems. - Initiated development of a new theoretical framework for optimization in the presence of high dimensional uncertain parameters.	4.350	16.947	19.357

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Initiated development of new model from uncertainty approaches that outperform traditional methods such as the Gaussian Process approach for accurate estimation of quantities of interest in physical systems. ***FY 2016 Plans:*** - Develop scalable approximation methods with provable error bounds for optimization in the presence of high dimensional uncertain parameters. - Develop scalable Bayesian inference algorithms for inverse methods with orders of magnitude speed-up incorporating the known physical properties of DoD systems. - Derive proofs and theoretical treatment of rare event detection algorithms within risk-based optimization framework. - Explore novel interfaces for computational design tools that incorporate material structures and physics to enable simultaneous design exploration and optimization under uncertainty. ***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. - Implement algorithms for estimation of quantities in physical systems in the presence of uncertainty on emerging high-performance computing platforms. - Develop new multi-fidelity techniques for model error estimation. - Demonstrate the use of novel computational design interfaces that incorporate material structures and physics to enable simultaneous design exploration and optimization under uncertainty.			
Title: Young Faculty Award (YFA) ***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 thirteen topic areas spanning from Quantum Science and Technology to Robotics and Supervised Autonomy, Mathematics, Computing, and the Interface of Engineering and Biology. 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 2015 Accomplishments:***	15.166	17.279	18.000

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Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Awarded new FY 2015 grants for new two-year research efforts across the topic areas, establishing a new set of appropriate technologies to solve current DoD problems. - Continued FY 2014 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. - Awarded Director's Fellowships for top FY 2013 participants based on researcher's refined technology development and transition plans. ***FY 2016 Plans:*** - Award new FY 2016 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 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. - Award 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.			
Title: Communicating With Computers (CWC) ***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 2015 Accomplishments:***	5.250	13.576	16.213

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Developed a hardware and a software platform for humans to communicate with machines using speech and gestures. - Formulated representations for the physical world that can capture the information in a visual scene in a form amenable to annotation and modification by language-based inputs. - Created a semantic framework for gesture, facial expression and other communicative modalities. ***FY 2016 Plans:*** - Explore methods for determining whether transmitted communications have been successfully received and, if not, what additional communications are most likely to result in success. - Implement representations for the physical world and develop connectors to large-scale knowledge bases to enable visual-language synergies. - Build a universal corpus of elementary composable ideas that in combination can convey the meaning of most communications. ***FY 2017 Plans:*** - Develop and demonstrate the capability to make computer inputs using gesture, facial expression and other communicative modalities. - Implement initial techniques for confirming that communications have been successfully received and extrapolating potentially missing information. - Demonstrate human-machine communication and collaboration on a physical problem solving task.			
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 likely defects and vulnerabilities in existing programs and to discover new 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 persistent semantic artifact generation and analysis, defect identification and repair, pattern recognition, and specification inference and synthesis. 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 2015 Accomplishments:*** - Implemented new static and dynamic program analysis techniques structured to interact with a persistent database of program facts collected from deep semantic analysis of a large software corpus. - Designed application programming interfaces and implementations of a preliminary mining engine that supports the efficient injection, querying, inspection, and optimization of the underlying database.	8.000	12.200	16.000

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Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Extended the corpus with richer semantic ontologies and metadata support to deal with diverse language frameworks, environments, and systems at scale. - Demonstrated an initial capability by automatically finding and repairing a Heartbleed bug through the addition of bounds checks. ***FY 2016 Plans:*** - Implement scalable database technologies and mining algorithms that allow the ingestion and analysis of tens of millions of lines of open-source software. - Integrate machine learning algorithms that can direct and assimilate mining activities on analysis artifacts stored in the database. - Evaluate component-level synthesis techniques to build implementations for complex self-contained algorithms. - Demonstrate the effectiveness of the developed systems. ***FY 2017 Plans:*** - Implement scalable database technologies and mining algorithms that allow the ingestion and analysis of hundreds of millions of lines of open-source software. - Apply deep learning algorithms on complex graph structures produced by corpus mining to discover latent relationships among corpus elements for automated program repair and synthesis. - Exploit ideas from 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.			
Title: Knowledge Representation ***Description:*** The Knowledge Representation thrust will develop much-needed tools to contextualize and analyze heterogeneous scientific data, facilitating field-wide hypothesis generation and testing. This will be accomplished by focusing on two key efforts: the development of domain-agnostic mathematical tools for representing heterogeneous data and 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 2015 Accomplishments:*** - Developed an initial mathematical knowledge framework for representing diverse data types and existing domain knowledge in a domain-agnostic form.	12.000	11.600	12.000

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Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Established initial scientific and/or engineering use case and example data sets that will be used to validate the knowledge representation framework and tools as they are developed. - Designed appropriate tools for ingesting and registering scientific data into a common mathematical representation and demonstrated the tools for example datasets. ***FY 2016 Plans:*** - Demonstrate data input and information extraction within the previously developed mathematical knowledge framework. - Incorporate domain-specific prior knowledge, such as computational models, into the mathematical knowledge framework. - Demonstrate the integration of datasets and prior domain knowledge in one or more scientific and engineering use cases. - Explore novel mathematical representations that can accommodate the possibilities of new materials for enabling simultaneous design exploration and optimization. - 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. - Explore novel experimental approaches for repeatable and replicable testing of social simulation representation and modeling tools for understanding social behavioral outcomes. ***FY 2017 Plans:*** - Develop a prototype platform for knowledge and data ingestion. - Demonstrate multimodal integration and inference with first-generation analysis tools. - Demonstrate hypothesis generation and steering using newly developed knowledge representation tools on one or more scientific and engineering use cases. - Analyze and optimize knowledge representation system performance in terms of scalability for inference and knowledge ingestion. - Demonstrate novel mathematical representation tools that integrate geometry with material physics and properties and micro-structure to accelerate design exploration and optimization. - Demonstrate the utility of new networked data collection, mathematical, and computational modeling tools in the simulation of complex social interactions. - Demonstrate the applicability of newly developed representation and modeling tools for understanding potential social behavioral outcomes. - 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.			
Title: Probabilistic Programming for Advancing Machine Learning (PPAML)	13.611	13.188	9.576

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Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
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 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 2015 Accomplishments:*** - Identified and developed two additional challenge problems from natural language processing and automated image captioning with increasing levels of complexity and larger data sets. - Extended the front end of a probabilistic programming system with additional functionality, including profilers, debuggers, and model verification/checking tools. - Extended the back end of a probabilistic programming system with additional functionality, such as improving efficiency of solvers and compiling inference engines to a range of different hardware targets. - Evaluated the performance of probabilistic programming approaches in collaboration with potential transition partners. ***FY 2016 Plans:*** - Demonstrate advanced probabilistic abstractions, inference techniques, and implementations. - Enrich the front end of probabilistic programming systems with new abstractions, and improve integration with solvers and inference engines. - Extend the back end of a probabilistic programming system with support for new inference techniques. - Evaluate the performance of each probabilistic programming system both in terms of the quality of the answers and the levels of resources required. ***FY 2017 Plans:*** - Demonstrate the benefit of probabilistic programming systems over existing techniques. - Integrate probabilistic systems within domain-specific contexts to provide tailored functionality. - Build new 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 the program-developed tools to relevant domains.			
Title: Secure Programming Languages (SPL)	-	-	12.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Description: The Secure Programming Languages (SPL) program will create new programming languages and integrated development environments that facilitate the creation of secure computer programs. At present, programming languages allow programmers to create programs having large attack surfaces, major flaws, and critical vulnerabilities. Minimizing the attack surface, correcting flaws, and eliminating vulnerabilities are the programmer's responsibility, and the degree to which the programmer succeeds depends largely on the skill of the programmer. The languages developed by SPL will break this paradigm by incorporating security features in the language itself that ensure formal correctness throughout all phases of the software development lifecycle. SPL languages and integrated development environments will facilitate the creation of software free from broad classes of flaws and vulnerabilities, and enable even novice programmers to readily create secure computer programs. ***FY 2017 Plans:*** - Formulate approaches for automatically identifying non-essential components in software programs and systems that can be eliminated to minimize the attack surface. - Develop programming languages, tools, and integrated development environments that facilitate the creation/adaptation of software free from broad classes of flaws and vulnerabilities. - Formulate approaches for automatically proving formal correctness at critical stages of the software development lifecycle.			
Title: Unconventional Processing of Signals for Intelligent Data Exploitation (UPSIDE) ***Description:*** The objective of the Unconventional Processing of Signals for Intelligent Data Exploitation (UPSIDE) program is to achieve extreme power savings while increasing performance for object detection and tracking from video streams by using an unconventional, approximate computing approach. Today, image processing applications use high precision, digital representations, which are inherently power-inefficient, particular for data produced by noisy, analog, real-time sensors such as video. UPSIDE's unconventional approach uses pattern matching techniques that map very efficiently to both analog complementary metal-oxide semiconductor (CMOS) circuits and various emerging devices. Furthermore, this pattern matching approach can leverage the physics of certain emerging devices to compute a best pattern match directly requiring very little power. The UPSIDE computing approach will be benchmarked using a DoD-relevant image processing pipeline, to verify gains in both throughput and power efficiency. The result will be new approach for image processing systems that demonstrate five orders of magnitude improvement, in terms of combined power and performance for the mixed signal implementations, and seven orders of magnitude improvements using the emerging devices. The UPSIDE program will create a new generation of computing structures that will, in turn, enable revolutionary advances in Intelligence, Surveillance and Reconnaissance (ISR) processing, particularly for DoD applications of embedded, real-time sensor data analysis. ***FY 2015 Accomplishments:***	20.000	18.000	-

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Completed an image processing pipeline system for performing object identification and tracking utilizing a newly developed probabilistic pattern match (inference) methodology, running on conventional digital processing hardware showing no loss in accuracy over standard methods. - Completed design of the mixed-signal CMOS chip(s) for doing inference computing in an image processing pipeline system and validated by an object identification and tracking simulation using real-time, high-definition video streams. - Fabricated mixed-signal CMOS chip(s) designed to perform inference computation for use in image processing. - Demonstrated the operation of (non-CMOS) emerging devices performing an inference computation, which can be scaled for use in portable, power constrained image processing applications. ***FY 2016 Plans:*** - Build and complete mixed-signal CMOS test bed for running image processing applications performing object ID and tracking. - Complete the digital version of image processing pipeline and validate power, performance and accuracy of UPSIDE inference methodology for object identification and tracking in surveillance video. - Complete final full test bed system demonstration of mixed signal CMOS chip(s) fabricated in the UPSIDE program showing significant power savings and performance increase (100,000x better combined) over digital version for object identification and tracking applications. - Complete evaluation of a simulation of the image processing pipeline system based on (non-CMOS) emerging devices, for the primary computing, projecting 1000x performance improvement while reducing power consumption of the processing by 10,000x with no loss in tracking accuracy as compared to the conventional image processing pipeline.			
Title: Graph-theoretical Research in Algorithm Performance & Hardware for Social networks (GRAPHS) ***Description:*** While the DoD has been extremely effective in deploying rigorous analytical and predictive methods for problems involving continuously valued variables (tracking, signals processing), analytical methods for discrete data such as graphs and networks have not kept pace. Recent evidence has shown that network analysis can provide critical insight when used in DoD-relevant scenarios. In this paradigm, nodes represent items of interest and their relationships or interactions are edges; the result forms a network or graph. Current analysis of large networks, however, is just in its infancy: the composition of real-world networks is understood only at the most coarse and basic details (diameter, degree distribution). In order to implement network techniques efficiently and usefully, a better understanding of the finer mathematical structure of these networks is needed. This includes the development of a comprehensive and minimal mathematical set that characterizes networks of DoD interest and a description of how these quantities vary in both space and time. ***FY 2015 Accomplishments:*** - Created a suite of systematic network analysis tools that can be applied to static and dynamic network structures and complex use cases.	4.902	2.900	-

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Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Developed near real-time scalable algorithms and models with guaranteed accuracy performance for inference, decision support, and understanding macro-phenomena. ***FY 2016 Plans:*** - Extend previously developed statistical graph models to enable the modeling of multi-scale graphs, heterogeneous and vector link structures. - Deliver code for streaming and scalable algorithms (graph matching, similarity, etc.) for large scale networks to be incorporated into software toolkit. - Deliver data-driven graph clustering and analysis methods that allow scientific discovery of complex time-varying phenomena.			
Title: Complexity Management Hardware ***Description:*** The battlefield of the future will certainly have more data generators and sensors that produce information required to efficiently execute operations. With networked sensors, the variety and complexity of the information streams will be even further extended. This project studied silicon designs which help alleviate the complexity inherent in next generation systems. These systems will have increasingly large data sets generated by their own multidomain sensors (such as RF and Electro-Optical/Infrared (EO/IR) payloads) as well as new inputs from external sensors that may or may not have been planned for initially. With current programming approaches, there are laborious coding requirements needed to assimilate new data streams. However, the context provided by these data sets is ever changing, and it is imperative for the integrated electronics to adapt to new information without a prolonged programming cycle. Providing contextual cues for processing of data streams will alleviate the fusion challenges that are currently faced, and which stress networked battlefield systems. As opposed to the intuition and future-proofing that is required at the programming stage of a current system, the silicon circuit of the future will be able to use contextual cues to adapt accordingly to new information as it is provided. The fundamental aspects of this program looked at various algorithms to explore the ability to use context to adapt to new information. Applied research for the program was budgeted in PE 0602303E, Project IT-02. ***FY 2015 Accomplishments:*** - Developed new, biology-inspired, neural network, machine learning algorithms including new data representations, low precision and ability to adapt and scale. - Identified and selected benchmark calculations on data streams to show accurate pattern recognition with minimal training times in a variety of applications.	3.614	-	-
Accomplishments/Planned Programs Subtotals	107.889	144.290	149.065

	FY 2015	FY 2016
Congressional Add: Basic Research Congressional Add	3.334	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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*

	FY 2015	FY 2016
FY 2015 Accomplishments: - Supports increased efforts in basic research that engage a wider set of universities and commercial research communities.		
Congressional Adds Subtotals	3.334	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CYS-01 / *CYBER SCIENCES*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
CYS-01: *CYBER SCIENCES*	-	48.178	50.428	45.000	-	45.000	47.219	27.000	10.000	10.000	-	-

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. During the past decade, information technologies have enabled important new military capabilities and driven the productivity gains essential to U.S. economic competitiveness. Unfortunately, during the same period, cyber threats have grown rapidly in sophistication and number, putting sensitive data, classified computer programs, and mission-critical information systems at risk. The basic research conducted under the Cyber Sciences project will produce the breakthroughs necessary to ensure 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 2015	FY 2016	FY 2017
Title: Transparent Computing	10.357	17.119	18.321

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, the result being that detection of attacks and anomalies must rely on narrow contextual information rather than complete knowledge of the event's provenance. This shortcoming facilitates attacks such as advanced persistent threats (APTs). The Transparent Computing program will address these problems by creating the capability to propagate security-relevant information 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 2015 Accomplishments:
- Formulated approaches for tracking information flows and other causal dependencies, and recovering event provenance to enable more effective detection of attacks, anomalies, and advanced persistent threats.
- Proposed active/continuous testing and adaptive security policy schemes that adjust security posture and usage controls in response to information provided by distributed protection components.
- Introduced dynamic behavioral attestation techniques, and proposed scalable algorithms and implementations.

FY 2016 Plans:
- Implement adaptive security policy schemes in software prototypes and perform initial assessments in simulated laboratory and cloud environments.
- Develop and implement behavioral attestation techniques in software prototypes scalable to big data applications.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) CYS-01 / *CYBER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop and implement 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 a preliminary integrated provenance tracking system for Android Java applications. - Develop defensive response mechanisms and a forensic analysis capability for a single system with browser and apps. - Conduct an adversarial evaluation of an APT browser implementation based on an operational APT scenario to infer the nature of the attack, against Transparent Computing-defined metrics.			
Title: Space/Time Analysis for Cybersecurity (STAC) ***Description:*** The Space/Time Analysis for Cybersecurity (STAC) program is developing techniques to detect vulnerabilities to algorithmic complexity 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 the next generation of attacks since they depend on intrinsic properties of the algorithms themselves rather than implementation flaws. News reports have highlighted the first wave of these attacks (CRIME, BREACH, Hash DoS). The STAC program seeks to develop new analysis tools and techniques to detect vulnerabilities to these attacks in the software upon which the U.S. government, military, and economy depend. ***FY 2015 Accomplishments:*** - Presented initial program analysis approaches for identifying vulnerabilities to algorithmic complexity and side channel attacks based on both time and space resource usage. - Developed STAC concept of operations, created example resource usage attack scenarios, and defined the rules of engagement for competitive experiments between research and adversarial challenge teams. - Identified the initial infrastructure required to support the development of a sufficient number of challenge programs containing known vulnerabilities to support realistic evaluations. ***FY 2016 Plans:*** - Define the formal semantics of the runtime environments in which vulnerable software runs and encode these semantics in a form consumable by automated analysis tools. - Produce initial analysis tools that reason about data and control flow paths in computer programs, identify inputs adversaries can use to mount algorithmic complexity attacks, and identify outputs that adversaries can use to mount side channel attacks.	12.239	15.078	16.360

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CYS-01 / *CYBER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Perform the first competitive experiment using prototype analysis tools to find vulnerabilities to algorithmic complexity and side channel attacks in a corpus of challenge programs, and produce measurements of research progress against program metrics. ***FY 2017 Plans:*** - Demonstrate capabilities to detect algorithmic resource usage vulnerabilities using automated program analysis based tools. - Assess the performance of tools that identify inputs adversaries can use to mount algorithmic complexity attacks and outputs that adversaries can use to mount side channel attacks. - 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.			
Title: SafeWare ***Description:*** The SafeWare program is developing new code obfuscation techniques for protecting software from reverse engineering. At present, adversaries can extract sensitive information from stolen software, which can include cryptographic private keys, special inputs/failsafe modes, proprietary algorithms and even the software architecture itself. Today's state of the art in software obfuscation adds junk code (loops that do nothing, renaming of variables, redundant conditions, etc.), which unfortunately does little more than inconvenience the aggressor. 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. The SafeWare program aims to take this very early-stage theory, which in its present form incurs too much runtime overhead to be practical, and re-tool its mathematical foundations such that one day it will be practical and efficient. As with RSA, SafeWare methods will require the solution of a computationally hard mathematical problem as a necessary condition for a successful de-obfuscation attack. ***FY 2015 Accomplishments:*** - Formulated new cryptographic approaches for protecting software from reverse engineering with mathematically proven security properties that are not substantially diminished in effectiveness even if they are fully understood by the adversary. - Introduced cryptographic code obfuscation methods with reduced program runtime overhead. - Studied the potential for implementing cryptographic code obfuscation techniques on multiprocessor systems. ***FY 2016 Plans:*** - Explore potentially powerful new primitives for cryptographic program obfuscation such as multilinear maps. - Develop alternate notions and models of obfuscation that accommodate specialized aggressor models. - Optimize domain-specific algorithms for obfuscation efficiency. - Create an evaluation platform/environment capable of quantifying runtime efficiency and cryptographic security of the obfuscation algorithms and software implementations, and initiate assessments. ***FY 2017 Plans:***	10.000	12.826	10.319

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CYS-01 / *CYBER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- 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. - Work with potential transition partners to incorporate specific obfuscation features and capabilities that address use cases relevant to military systems and missions.			
Title: Automated Program Analysis for Cybersecurity (APAC) ***Description:*** Automated Program Analysis for Cybersecurity (APAC) is developing automated program analysis techniques for mathematically validating specified security properties of mobile applications. This will involve creating new and improved type-based analysis, abstract interpretation, and flow-based analysis methods with far greater ability to accurately demonstrate security with lower instances of false alarms. APAC technologies will enable developers and analysts to identify mobile applications that contain hidden malicious functionality and bar those applications from DoD mobile application marketplaces. ***FY 2015 Accomplishments:*** - Significantly improved the productivity of analysts to bar malware from DoD application stores using the prototype tools. - Assessed and selected prototype tools for experimentation or transition based on their performance on program metrics: probabilities of false alarm, missed detection rate, and human analysis time. - Transitioned new program analysis techniques to major commercial industry products. ***FY 2016 Plans:*** - Run comparative performance evaluations between program-developed malware detection tools and commercially available tools. - Engage in experiments and pilot deployments of prototype tools with transition partners running DoD application stores. - Improve prototypes to enhance usability in the context of DoD application stores.	12.248	5.405	-
Accomplishments/Planned Programs Subtotals	44.844	50.428	45.000

	FY 2015	FY 2016
Congressional Add: Basic Research Congressional Add ***FY 2015 Accomplishments:*** - Supports increased efforts in basic research that engage a wider set of universities and commercial research communities.	3.334	-
Congressional Adds Subtotals	3.334	-

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, **RDT&E Project Justification:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CYS-01 / *CYBER SCIENCES*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
ES-01: *ELECTRONIC SCIENCES*	-	39.947	40.824	49.553	-	49.553	38.151	40.996	44.883	44.883	-	-

A. Mission Description and Budget Item Justification

This project seeks to continue the phenomenal progress in microelectronics innovation that has characterized the last decades by exploring and demonstrating electronic and optoelectronic devices, circuits and processing concepts that will: 1) provide new technical options for meeting the information gathering, transmission and processing required to maintain near real-time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near real-time; and 2) provide new means for achieving substantial increases in performance and cost reduction of military systems providing these capabilities. Research areas include new electronic and optoelectronic device and circuit concepts, operation of devices at higher frequency and lower power, extension of diode laser operation to new wavelength ranges relevant to military missions, development of uncooled and novel infrared detector materials for night vision and other sensor applications, development of innovative optical and electronic technologies for interconnecting modules in high performance systems, research to realize field portable electronics with reduced power requirements, and system and component level improvements to provide greater affordability and reliability. Additionally, electronically controlled microinstruments offer the possibility of nanometer-scale probing, sensing and manipulation for ultra-high density information storage "on-a-chip," for nanometer-scale patterning, and for molecular level analysis and synthesis. These microinstruments may also offer new approaches to integration, testing, controlling, manipulating and manufacturing nanometer-scale structures, molecules and devices.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Semiconductor Technology Advanced Research Network (STARNet)	20.000	20.000	20.000

Description: The Semiconductor Technology Advanced Research Network (STARNet) program is a government-industry partnership, combining the expertise and resources from select defense, semiconductor, and information companies with those of DARPA, to sponsor an external set of academic research teams that are focused on specific technology needs set by experts in industry and government. Efforts under this program will remove the roadblocks to achieving performance needed for future sensing, communication, computing, and memory applications. The program involves close collaboration between these experts and the academic base, with industry providing 60% of program funding matched by 40% from DARPA. For both industrial and government participants, leveraging shared research funding for high risk, pre-competitive technology explorations focused on shared technical hurdles is very attractive.

Research in STARNet is divided into a discovery thrust (ACCEL) and an integration thrust (NEXT) executed by virtual academic centers and focused on exploiting current and emerging technologies to provide new capabilities. ACCEL seeks to discover new material systems, devices, and novel computing/sensing architectures. NEXT involves projects on advanced analog and mixed signal circuitry, complex system design tools, and alternative computing architectures. As the projects in ACCEL mature, it is expected that they will replace the efforts in NEXT that are based on current standard technologies for integrated circuits.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017

The STARNet program creates a community where industry and government participate as co-sponsors to guide and learn from a large academic research base (including approximately 42 universities, 171 faculty researchers, 638 students, and more than 109 industry associate personnel), with DoD shaping the goals to have direct impact on important long-range DoD needs.

FY 2015 Accomplishments:
- Investigated the feasibility of advanced two-dimensional semiconductor materials for extremely low power devices and developed the nanofabrication methods as well as established the theory, modeling and simulation tools for 2D electronic materials.
- Researched fundamental limitations of scaling multifunctional and spintronics materials. Demonstrated advanced devices and examined device characteristics.
- Developed scalable silicon-based computing system architecture by exploring the benefits of heterogeneously integrating emerging nano-technologies into silicon-based designs.
- Developed statistical foundations of information processing via machine learning frameworks, process-scalable foundations of analog mixed-signal systems using information-based design metrics, neuro-principled information processing architectures for Beyond-complementary metal-oxide semiconductor (CMOS) and CMOS fabrics, and accelerated the deployment of beyond-CMOS and CMOS nanoscale fabrics via nanofunctions and nanoprimitives.
- Developed components, architecture, data control, and tools for sensor swarm applications such as building energy efficiency, health care delivery, manufacturing and agriculture, and warfighter situational awareness.

FY 2016 Plans:
- Develop novel materials and steep-turn-on transistor devices as well as design 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.
- Develop voltage-controlled magnetic materials and fabrication techniques to enable power efficient spintronics devices for logic and memory applications.
- Develop the scalability of silicon-based computing system concepts into the 2020-2030 timeframe to meet the performance, power and cost demands of DoD applications.
- Discover and develop bio- and neuro-inspired information processing architecture framework that approaches the efficiency of brain computation, while aligning well with emerging beyond-CMOS nanoscale fabrics.
- Investigate sensor swarm applications for Defense requirements such as warfighter situational awareness and assess system characteristics and potential advantages.

FY 2017 Plans:

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Develop low-voltage steep-turn-on transistors beyond traditional CMOS devices as well as realize the digital, memory, or microwave circuits with extremely low power consumption. - Develop spintronics devices for extremely low-power for logic and non-volatile memory circuits with increased complexity. - Develop heterogeneous and domain accelerated parallel systems by leveraging novel silicon-based computing architecture and integration concepts to enable reliable and secure system designs. - Develop statistical information processing architectures for in-memory computing and in-sensor computing by CMOS and beyond CMOS prototypes. - Develop 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: Direct On-Chip Digital Optical Synthesis (DODOS) ***Description:*** The development of techniques for precise frequency control of radio frequencies (RF) and microwave radiation in the 1940's revolutionized modern warfare. Frequency control is the enabling technology for radar, satellite and terrestrial communications, and positioning and navigation technology, among many other core DoD capabilities. By comparison, frequency control at optical frequencies is relatively immature, comparable to the state-of-the-art of microwave control in the 1930's. The first practical demonstration of optical frequency synthesis, utilizing a self-referenced optical comb, was performed in 1999 and, since that time, the precision and accuracy of optical measurements has improved by four orders of magnitude, including the demonstration of atomic clocks utilizing optical-frequency atomic transitions that far outperform existing technology based on microwave transitions. To date, however, optical frequency control has been constrained to laboratory experiments due to the large size, relative fragility, and high cost of optical comb-based synthesizers. Recent developments in self-referenced optical frequency combs in microscale resonators enable the development of a fully-integrated chip-scale optical frequency synthesizer. Ubiquitous low-cost robust optical frequency synthesis is expected to create a similar disruptive capability in optical technology as microwave frequency synthesis did in the 1940's, enabling high-bandwidth coherent optical communications, coherent synthesized-aperture LiDAR, portable high-accuracy atomic clocks, high-resolution standoff gas/toxin detection, and intrusion detection, among other foreseen applications. The Direct On-chip Digital Optical Synthesis (DODOS) program will investigate high-performance photonic components for creating a microscale high-accuracy optical frequency synthesizer in a compact robust package, suitable for deployment in a wide variety of mission-critical DoD applications. Significant challenges in the program include reducing the power threshold and stabilizing microresonator optical combs, developing efficient devices for on-chip second harmonic generation, and characterizing the frequency stability and phase noise of a slave laser locked to the stabilized comb. Applied research for this program is funded within PE 0602716E, Project ELT-01. ***FY 2015 Accomplishments:***	8.181	9.700	7.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Optimized wavelength dispersion and low-threshold operation of microresonator based combs. - Explored materials and novel devices for efficient on-chip second harmonic generation. ***FY 2016 Plans:*** - Demonstrate compact low-threshold self-referenced combs suitable for DODOS integration. - Demonstrate methods for stabilizing the phase coherence of a microresonator comb across a broad optical bandwidth. - Characterize the output of a slave laser locked to a stabilized microresonator comb and evaluate 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 nanometer (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.			
Title: Near Zero Energy RF and Sensor Operations (N-ZERO) ***Description:*** The DoD has an unfilled need for a persistent, event driven sensing capability, where physical, electromagnetic and other sensors can be pre-placed and remain dormant until awoken by an external trigger or stimulus. State-of-the-art sensors use active electronics to monitor the environment for the external trigger. The power consumed by these electronic circuits limits the sensor lifetime to durations of weeks to months. The Near Zero Power RF and Sensor Operations (N-ZERO) program will extend the lifetime of remotely deployed sensors from months to years. N-ZERO will develop the underlying technologies and demonstrate the capability to continuously and passively monitor the environment and wake-up an electronic circuit upon detection of a specific signature or trigger. Thereafter, sensor lifetime will be limited only by processing and communications of confirmed events. This program will investigate the development of highly innovative sensors and sensor architectures as well as signal processing and digitization technologies with near zero power consumption. In particular, a fundamental understanding of the trade space that simultaneously minimizes power consumption, the minimum detectable signal, and the probability of false detection will be explored. This program also has related applied research efforts funded under PE 0602716E, Project ELT-01. ***FY 2015 Accomplishments:*** - Performed data collection measurements for the purpose of designing and evaluating the performance of N-ZERO devices and microsystems in DoD relevant environments. Data collections included signatures and environmental background in acoustic,	1.600	2.500	3.800

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
vibrational and magnetic modalities, and environmental background data in radio frequencies (RF) of the electromagnetic spectrum. ***FY 2016 Plans:*** - Design and fabricate near zero power digitization technologies for zero power RF and physical sensor wake-up circuits. - Design and fabricate passive and extremely low power analog and digital signal processing technologies for low energy processing of RF and physical sensor signatures. - Design and fabricate innovative RF and physical sensor designs that perform passive voltage amplification and spectral processing. ***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. - Investigate transition paths for fundamental technologies into RF communications and physical sensor systems under development in the applied research portion of this project.			
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) ***Description:*** The effectiveness of combat operations across all domains increasingly depends on our ability to control and exploit the electromagnetic (EM) spectrum, and to deny its use to our adversaries. Below 30 GHz, the proliferation and availability of inexpensive high-power commercial RF sources has made the EM spectrum crowded and contested, challenging our spectrum dominance. The numerous tactical advantages offered by operating at higher frequencies, most notably the wide bandwidths available, is driving both commercial and DoD solid-state and vacuum electronic amplifiers into the millimeter wave (mm-wave) spectrum above 30 GHz. Control of the mm-wave spectrum necessitates advanced and increasingly more sophisticated electronic components and systems. The performance of these systems strongly depends on the available amplifier power. The High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) program will fund basic research in the area of vacuum electronics with the ultimate goal of improving the fundamental understanding of the various phenomena governing the science and technology for the next generation of 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 Plans:***	-	4.000	4.000

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Begin research into high-fidelity, three-dimensional, multi-physics, numerically efficient modeling and simulation techniques that lead to first-pass design success. - Begin investigating advanced manufacturing methods such as Selective Laser Sintering (SLS) and other additive manufacturing methods for beam-wave interaction circuits and other tube components. - 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 2017 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) ***Description:*** The DoD relies on GPS for ubiquitous and accurate positioning, navigation, and timing (PNT). With the increased prevalence of intentional GPS jamming, spoofing, and other GPS-denial threats, GPS access is increasingly unavailable in contested theaters and alternative sources of PNT are required. In particular, guided munitions navigation is the most immediate and among the most demanding of GPS-denial challenges, due to the necessity of operating in highly contested theaters and the stringent requirements for minimization of cost, size, weight, and power consumption (CSWaP). The Precise Robust Inertial Guidance for Munitions (PRIGM) program will develop low-CSWaP inertial sensor technology for GPS-free munitions navigation. PRIGM comprises two focus areas: 1) Development of a Navigation-Grade Inertial Measurement Unit (NGIMU) that transitions state-of-the-art micro-electro-mechanical systems (MEMS) to DoD platforms by 2020; and 2) Research and development of Advanced Inertial MEMS Sensors (AIMS) to achieve gun-hard, high-bandwidth, high dynamic range navigation requirements with the objective of complete autonomy in 2030. PRIGM will advance state-of-the-art MEMS gyros from TRL-3 devices to a TRL-6 transition platform (complete IMU) that enables Service Labs to perform TRL-7 field demonstrations. PRIGM will exploit recent advances in heterogeneous integration of photonics and complementary metal-oxide semiconductor (CMOS) and advanced MEMS technology to realize novel inertial sensors for application in extreme dynamic environments and beyond navigation-grade performance. Future warfighting scenarios will take place in a GPS-denied world. When GPS is not available inertial sensors will provide autonomous positioning and navigation information. For successful transition to the warfighter, these sensors need to be low-CSWaP, have unprecedented precision and stability, and be immune to the perturbations of external vibrations and temperature fluctuations. PRIGM will identify, investigate, and demonstrate novel inertial sensing schemes that are capable of being	-	4.624	4.753

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
miniaturized once proof of concept is complete. Advanced research efforts are funded in PE 0602716E, Project ELT-01 and advanced development efforts funded in PE 0603739E, Project MT-15. ***FY 2016 Plans:*** - Develop models to simulate novel chip-scale inertial sensors such as optical waveguide gyroscopes and optically interrogated MEMS gyroscopes and accelerometers. - Develop MEMS and photonic integration processes demonstrating new and novel approaches to inertial sensing. - Build experimental test setup to support short-loop experiments for development of novel photonic-MEMS gyroscopes and accelerometers. ***FY 2017 Plans:*** - Integrate component technology and demonstrate photonic-MEMS inertial sensors with beyond-navigation-grade stability and precision. - Optimize novel optical and MEMS inertial sensor designs through modeling and simulation after completing initial experimental characterization. - Test navigation-grade inertial sensor performance robustness to external perturbations such as vibration and shock.			
Title: Quantum and Materials Basics ***Description:*** Advanced materials and novel devices have often become the basis for new and asymmetric military capabilities. The adoption of Gallium arsenide (GaAs) monolithic microwave integrated circuits greatly increased the range and effectiveness of U.S. radar systems, and recently matured Gallium Nitride (GaN) technology will be deployed with even greater capabilities. However these major investments were only possible after materials were advanced to a level of maturity that a device program could be executed. The Quantum and Materials Basics (QMB) program will investigate basic materials and device physics to mature concepts to the point that functioning components could be tested. These materials promise performance that will radically change future military systems, far exceeding the state of the art but only after they can be matured. The community is pushing towards the ultimate limits set by quantum mechanics, and managing this scaling requires fundamental research. Promising avenues of research include highly linear 1D and 2D devices and materials that would increase the dynamic range of RF transceivers; coupling of electrical, acoustic, and/or optical fields to significantly reduce the size and improve performance of RF components; and addressing the most outstanding challenges to deploying timing and sensing devices based on modern atomic physics and technology. ***FY 2017 Plans:*** - Select candidate devices and materials for QMB development and maturation. - Determine performance targets by using basic material parameters and physics to extrapolate the limits of future military capabilities.	-	-	10.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Perform proof-of-concept demonstrations to prioritize the most critical development challenges. - Create simplified devices such as transistors out of the selected materials.			
Title: Microscale Plasma Devices (MPD) ***Description:*** The goal of the Microscale Plasma Devices (MPD) program was to design, develop, and characterize MPD technologies, circuits, and substrates. The MPD program focused on development of fast, small, reliable, high carrier-density, micro-plasma switches capable of operating in extreme conditions, such as high-radiation and high-temperature environments. Specific focus was given to methods that provide efficient generation of ions that can perform robust signal processing of RF through light electromagnetic energy over a range of gas pressures. Applications for such devices are far reaching, including the construction of complete high-frequency plasma-based circuits, and microsystems with superior resistance to radiation and extreme temperature environments. MPDs were developed in various circuits and substrates to demonstrate the efficacy of different approaches. MPD-based microsystems are demonstrated in DoD applications where electronic systems must survive in extreme environments. The Basic Research part of this effort focused on fundamental MPD research to advance scientific knowledge based on the study of several key MPD design parameters. These parameters included ultra-high pressure and high carrier density regimes. MPD focused on expanding the design space for plasma devices enabling revolutionary advances in micro-plasma device performance. MPD developed innovative concepts and technologies that are clearly disruptive with respect to the current state of the art in terms of switching speed (less than 100 picoseconds), carrier density (exceeding 1E18 per cubic centimeter), and capable of operation and robustness in extreme high-radiation or high-temperature (600degC) environments. Fundamental scientific knowledge derived from MPD is also expected to drive developments in commercialization of MPD technology developed and funded in PE 0602716E, Project ELT-01. ***FY 2015 Accomplishments:*** - Completed investigations examining scaling properties for plasma devices in terms of size, density, robustness and switching speed. - Finalized studies on fundamental frequency, efficiency and power limitations of generating high-power microwave through terahertz (THz) frequency signals utilizing plasma as a robust, non-linear up-conversion medium. - Completed the optimization of devices that perform from RF through light frequencies. - Transitioned fundamental research findings into improved commercial modeling simulation and design tool capabilities, enabling DoD relevant applications that require survivability in extreme radiation and temperature environments.	2.000	-	-
Title: Micro-coolers for Focal Plane Arrays (MC-FPA)	1.500	-	-

Exhibit R-2A, **RDT&E Project Justification:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
Description: The Micro-coolers for Focal Plane Arrays (MC-FPA) program developed low size, weight, power, and cost (SWaP-C) cryogenic coolers for application in high-performance infrared (IR) cameras. It is well known that the sensitivity of an IR focal-plane array (FPA) is improved by cooling its detectors to cryogenic temperatures. The disadvantages of state-of-the-art cryo-coolers are their large size, high power and high cost. On the other hand, thermoelectric (TE) coolers used in low performance IR cameras are relatively small, but are inefficient, and it is difficult to achieve temperatures below 200 Kelvin (K). To reduce IR camera SWaP-C, innovations in cooler technology are needed. This program exploited the Joule-Thomson (J-T) cooling principle, in a silicon-based Micro Electro-Mechanical Systems (MEMS) technology, to develop and demonstrate wafer-scale integrated micro-cryogenic IR FPA coolers with very low SWaP-C. MEMS microfluidics, piezoelectric MEMS, and CMOS electronics were used to demonstrate an integrated cold head and compressor, all in a semiconductor chip. This program has related applied research efforts funded under PE 0602716E, Project ELT-01. ***FY 2015 Accomplishments:*** - Demonstrated single-stage J-T cooling chip with external compressor. - Completed design and began development of the extended shortwave IR FPA. - Began preliminary design of a 3-stage J-T micro-cooler.			
Accomplishments/Planned Programs Subtotals	33.281	40.824	49.553

	FY 2015	**FY 2016**
Congressional Add: Basic Research Congressional Add	6.666	-
FY 2015 Accomplishments: - Supports increased efforts in basic research that engage a wider set of universities and commercial research communities.		
Congressional Adds Subtotals	6.666	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
MS-01: *MATERIALS SCIENCES*	-	77.942	53.060	65.609	-	65.609	60.387	63.780	85.138	85.138	-	-

A. Mission Description and Budget Item Justification

This project provides the fundamental research that underpins the development and assembly of advanced nanoscale and bio-molecular materials, devices, and electronics for DoD applications that greatly enhance soldier awareness, capability, security, and survivability, such as materials with increased strength-to-weight ratio and ultra-low size, devices with ultra-low energy dissipation and power, novel spectroscopic sources, and electronics with persistent intelligence and improved surveillance capabilities.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Nanoscale/Bio-inspired and MetaMaterials	22.140	17.210	21.300

Description: The research in this thrust area exploits advances in nano/micro-scale and bio-inspired materials, including computationally based materials science, in order to develop unique microstructures, material properties, and functionalities. This area also includes efforts to develop the underlying science for the behavior of materials whose properties have been engineered at the nano/micro-scale level, including metamaterials, bio-inspired materials for sensing and actuation, and materials that are designed to mimic biological materials from molecular to macroscopic function. Specific examples of areas of interest include materials that can self-repair, adapt, and respond for soldier protection against chemical and biological threats and novel approaches to optical based or metamaterial imaging systems capable of detecting objects in cluttered environments and around or through structural obscurants leveraging multiple degrees of freedom of light and using all photon pathways.

FY 2015 Accomplishments:
- Developed a method for screening non-natural polymer libraries for designed properties such as binding to target molecules.
- Developed a method for sequencing non-natural polymers at low concentrations.
- Analyzed the statistics of direct vs indirect path photons from an object in a scene, as captured by traditional imaging systems.
- Analyzed the statistics of direct vs indirect path photons for imaging objects in different scenes, including inside a building, in an urban canyon, and in a military tank formation.

FY 2016 Plans:
- Use non-natural polymer synthesis and screening system to create affinity reagents against DARPA-defined targets.
- Develop strategy to adapt the non-natural polymer synthesis and screening system to modify affinity reagent properties.
- Initiate the development of a foundational theoretical framework, based on the Plenoptic function, for exploring the limits of exploiting multiple degrees of freedom of light and extracting the maximum amount of information from complex scenes.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Initiate the design of experiments to validate theoretical models for 3D scene rendering using multiple degrees of freedom of light. ***FY 2017 Plans:*** - Improve the binding affinity of non-natural polymers against DARPA-defined targets. - Generalize developed non-natural polymer library screening strategies across multiple target classes. - Continue the development of a comprehensive Plenoptic function theoretical framework for extracting information for all photon pathways in a complex scene rendering. - Theoretically determine the fundamental limits of maximum light/scene information extraction from a single viewpoint. - Conduct laboratory experiments to validate the theoretical predictions for maximum information extraction from complex scenes using the multiple degrees of freedom described by the Plenoptic function.			
Title: Fundamentals of Nanoscale and Emergent Effects and Engineered Devices ***Description:*** The Fundamentals of Nanoscale and Emergent Effects and Engineered Devices program seeks to understand and exploit a broad range of physical properties and new physics that emerge as a result of material and/or device structure and organization at nano-scale dimensions and/or at extreme temperature and pressure. There are a wide variety of material properties that currently exist only at the nanoscale including quantized current-voltage behavior, very low melting points, high specific heats, large surface to volume ratio, high efficiency catalysis, enhanced radiative heat transfer, and correlated electron effects that arise in low dimensional systems. In addition, extreme high pressure conditions can lead to new material polymorphs or phases with dramatically enhanced physical, mechanical and functional properties. The focus of this thrust is to further characterize these emergent properties and to identify new synthesis approaches to enable access to these properties in stable, bulk material systems suitable for a wide range of DoD applications. The insights gained from research performed under this thrust will enable new, more efficient, and powerful material and device architectures that will benefit many DoD applications including controllable photonic devices that operate over multiple wavelengths, ultra-high sensitivity magnetic sensors, high-throughput biochemical sensors for known and unknown (engineered) molecules, ultra-precision air and water purification systems, materials for hypersonic aircraft, and advanced armor protection. ***FY 2015 Accomplishments:*** - Continued synthesis of suites of intermediates to lead to selected extended solids. - Initiated characterization of the physical, structural, and chemical properties of intermediates synthesized. - Furthered the development of methods to stabilize extended solids at ambient temperatures and pressures. - Based on computational analysis and experimental results, initiated design retrosynthetic pathways that are synthetically achievable for multistep reaction schemes to fabricate extended solids at reduced pressures. - Identified novel approaches for enabling three dimensional (3D) assemblies of nanoscale material constructs into micron-scale structures while preserving desirable nanoscale material properties.	16.543	14.100	20.045

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Selected candidate nanoscale material systems with superior material properties that are amenable to 3D assembly processes. - Identified promising pick and place technologies for assembling 3D micron-scale constructs into cm-scale structures. - Began to explore the ability to assemble micron-scale, 3D, and multiple material structures from nanoscale material constructs while reserving desirable nanoscale material properties. - Initiated the pick and place assembly of cm-scale materials from micron-scale constructs while preserving desirable nanoscale material properties. ***FY 2016 Plans:*** - Continue development of methods to stabilize extended solids at ambient temperatures and pressures. - Demonstrate synthesis and stability to ambient temperature and pressure of high density extended carbon-based materials (e.g., clathrates, allotropes, and oxides) at the multimilligram scale. - Explore scalable production methods for fabrication of tough ceramic materials. - Refine and implement development of retrosynthetic pathways that are synthetically achievable for multistep reaction schemes to fabricate extended solids at reduced pressures based on computational analysis and stabilization results. - Further demonstrate the ability to assemble micron-scale, 3D, and multiple material structures from nanoscale material constructs while preserving desirable nanoscale material properties. - Continue to demonstrate pick and place assembly of cm-scale materials from micron-scale constructs while preserving desirable nanoscale material properties. - Initiate development of a computational framework for predicting the emergence of non-linear effects in complex systems. - Design an open source, agent based hardware/software platform for evaluating algorithms for modeling non-linear effects in complex systems across multiple scales. ***FY 2017 Plans:*** - Demonstrate development of methods to stabilize extended solids at ambient temperatures and pressures. - Demonstrate synthesis and stability to ambient temperature and pressure of high density extended carbon-based materials (e.g., clathrates, allotropes, and oxides) at the gram scale. - Demonstrate fabrication at the >100 gram scale and validation testing of tough ceramic materials. - Demonstrate multistep reaction synthetic pathways based on retrosynthetic designs 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 at the nanometer to micron scales. - Build 1 cm or larger structures with controlled internal complexity from feedstock consisting of individual atoms or molecules. - Demonstrate the ability to exploit the computing capacity offered by nonlinear systems to simulate nonlinear dynamical systems.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop analog computing substrates for efficiently simulating systems governed by complex non-linear phenomena.			
Title: Basic Photon Science ***Description:*** The Basic Photon Science thrust is examining the fundamental science of photons, and their interactions in integrated devices, from their inherent information-carrying capability (both quantum mechanically and classically), to novel modulation techniques using not only amplitude and phase, but also orbital angular momentum. The new capabilities driven by this science will impact DoD through novel approaches to communications, signal processing, spectroscopic sensing, and imaging applications. For example, fully exploiting the computational imaging paradigm and associated emerging technologies will ultimately yield ultra-low size, weight, and power persistent/multi-functional intelligence, surveillance, and reconnaissance systems that greatly enhance soldier awareness, capability, security, and survivability. One focus of this thrust is to explore approaches for optical frequency division and harmonic generation for applications such as time distribution from ultrastable optical clocks, ultra-low phase noise microwaves, frequency references, table-top sources of coherent x-rays, and isolated attosecond pulses. In addition, this thrust will pursue novel, chip-scale optical frequency comb sources and associated technologies throughout the electromagnetic spectrum for spectroscopic sensing and demonstrate their performance with proof-of-concept studies in targeted applications. These sources will enable and spawn entirely new fields in simultaneous remote sensing, identification, and quantification of multiple trace materials in spectrally cluttered backgrounds. ***FY 2015 Accomplishments:*** - Demonstrated 30 GHz microwave output from a silica disk microresonator-based optical frequency comb and high-power photodiodes for chip-based, ultra-low phase noise microwave generation. - Demonstrated on-chip frequency comb and pulse shaping components utilizing indium phosphide based photonic integrated circuit technology and evaluated with bulk scale reference combs. - Demonstrated high flux soft x-ray production in the biologically critical water window spectral region and used this source for preliminary x-ray imaging demonstrations on the nanometer scale. - Demonstrated high efficiency-per-shot laser driven neutron production and constructed increased repetition rate sample target inserter and laser amplifiers to improve overall neutron flux for radiography applications. - Demonstrated and controlled ultra-high intensity, long wavelength lasers, which can be used to generate high average power, high energy isolated attosecond (the timescale of electron dynamics in atoms and molecules) optical pulses. - Developed and controlled microresonator-based frequency comb sources in the mid-infrared spectral region. - Developed and controlled microresonator-based frequency comb sources in the visible spectral region. - Demonstrated proof-of-concept studies of coherent control concepts for frequency comb-based spectroscopic sensing. ***FY 2016 Plans:*** - Design a rack mounted package for mode-locked laser based optical frequency division microwave source. - Demonstrate RF photonic bandpass filtering with micro-resonator optical frequency combs.	19.400	21.750	24.264

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Demonstrate a remotely operating quartz microwave oscillator slaved via optical frequency comb based free-space (wireless) time and frequency transfer. - Demonstrate femtosecond time-resolved imaging at the nanometer scale with soft x-rays generated via high harmonic generation (tabletop scale x-ray source). - Demonstrate stability and characterization capabilities of extreme ultraviolet/soft x-ray attosecond end-station by measuring and characterizing isolated attosecond (10^-18 seconds) pulses. - Demonstrate proof-of-concept broadband chip-scale comb sources in multiple spectral regions. - Demonstrate proof-of-concept dual-comb quantum cascade lasers on the same chip in mid-infrared. - Demonstrate massively parallel spectroscopy in a lab setting for the detection of multiple trace species in a cluttered environment using chip-scale frequency combs in multiple spectral regions. - Investigate the fundamental limits of photon transduction to enable a mechanistic description of the photodetector trade space including timing, resolution, efficiency and speed. ***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 bio-imaging 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 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. - Determine a quantitative, first-principles description of photon detector performance for specific DoD platforms.			
Title: Enabling Quantum Technologies ***Description:*** This thrust emphasized a quantum focus on technology capabilities including significantly improved single photon sources, detectors, and associated devices useful for quantum metrology, communications, and imaging applications. It also exploited novel optical nonlinearities that can be used to combine quantum systems with classical coherent pulses to enable secure quantum communications over conventional fiber at rates compatible with commercial telecommunications. In addition, this thrust examined other novel classes of materials and phenomena that have the potential to provide novel capabilities in	13.193	-	-

Exhibit R-2A, **RDT&E Project Justification:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** MS-01 / *MATERIALS SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
the quantum regime, such as GPS-independent navigation via atom interferometry and communications, and ultrafast laser technologies. ***FY 2015 Accomplishments:*** - Developed improvements towards compact optomechanical gyroscopes. - Demonstrated techniques with better than 50 nm resolution with applications towards magnetic imaging of living cells. - Began studies to sense functional changes of electronic spin labels in biomolecules (e.g., proteins, lipids) with high spatial and temporal resolution. - Validated optimized performance of slow-beam-optical-clock. - Integrated prototype macroscopic quantum communications systems into local quantum communications testbeds. - Quantified performance of prototype macroscopic quantum communications system under realistic conditions (loss, noise, decoherence) and over secure long haul communications distances. - Developed an initial mathematical framework for predicting the emergence of quantum behavior in complex systems.			
Accomplishments/Planned Programs Subtotals	71.276	53.060	65.609

	FY 2015	**FY 2016**
Congressional Add: Basic Research Congressional Add ***FY 2015 Accomplishments:*** - Supported increased efforts in basic research that engage a wider set of universities and commercial research communities.	6.666	-
Congressional Adds Subtotals	6.666	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) TRS-01 / *TRANSFORMATIVE SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
TRS-01: *TRANSFORMATIVE SCIENCES*	-	30.740	38.390	53.070	-	53.070	56.632	68.102	69.617	69.056	-	-

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 2015	FY 2016	FY 2017
Title: Living Foundries	10.250	9.250	7.185

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.

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 2015 Accomplishments:
- Examined design tool innovations to enable forward engineering of novel genetic systems.
- Investigated evaluation tools to enable massively parallel testing, validation, and verification of engineered systems.
- Continued development of automated and scalable, large-scale DNA assembly and editing tools and processes.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Researched new methods for integrated feedback to exploit high volume data generation and inform future designs and processes. ***FY 2016 Plans:*** - Begin demonstrating forward engineering of novel genetic systems using innovative computational design tools. - Implement evaluation tools for high-throughput testing, validation, and verification of engineered systems. - Implement novel learning systems that enable iterative design of engineered systems using integrated feedback of results to inform subsequent designs. - Incorporate automated and scalable, large-scale DNA assembly, editing tools and processes into automated, integrated design-build-test-learn technologies for engineering novel biological systems. - Develop 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.			
Title: Open Manufacturing ***Description:*** The Open Manufacturing program will reduce barriers to manufacturing innovation, speed, and affordability of materials, components, and structures. This will be achieved by investing in technologies to enable affordable, rapid, adaptable, and energy-efficient manufacturing, to promote comprehensive design, simulation and performance-prediction tools, and exposure to best practices. The applied research component of this program is funded in PE 0602715E, Project MBT-01 under Materials Processing and Manufacturing. ***FY 2015 Accomplishments:*** - Developed basic architecture and statistical environment to enable rapid qualification and certification approaches through the interaction and use of probabilistic models for process, design, and materials. - Demonstrated Micro-Induction Sintering (MIS) method for additive manufacture of metal and/or ceramic materials in complex geometries. - Demonstrated an approach to verify, validate, and quantify uncertainty in the developed rapid qualification frameworks. ***FY 2016 Plans:***	3.750	2.038	1.800

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Characterize material produced using micro-induction sintering process. - Develop fundamental process modeling tools for micro-induction sintering process. - Demonstrate approach to integrate the Open Manufacturing rapid qualification frameworks into a comprehensive computational tool. ***FY 2017 Plans:*** - Establish process limits for micro-induction sintering process for specific ceramic and/or refractory material. - Analyze and quantify ability to accurately predict material properties of refractory and metal matrix composites produced using micro-induction sintering through process models previously developed, integrated with the overall Open Manufacturing framework. - 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.			
Title: Biological Robustness in Complex Settings (BRICS) ***Description:*** The Biological Robustness in Complex Settings (BRICS) program will leverage newly developed technologies to enable radical new approaches for engineering biology. An emerging field, engineering biology is focused on developing the tools to harness the powerful synthetic and functional capabilities of biology. These tools will facilitate design and biological production of new chemicals and materials, sensing capabilities, therapeutics, and numerous other applications. This rapidly developing technological capability opens the door to new applications that have previously been out of reach, and offers substantial potential advantages in terms of cost and novel functionality. Fundamental work in this area will focus on understanding the underlying principles for engineering robust and safe microbes and microbial communities that perform as designed over the long-term. This program has applied research efforts funded in PE 0602715E, Project MBT-02. ***FY 2015 Accomplishments:*** - Initiated investigation of methods to engineer microorganisms that are stable over long time periods under complex growth conditions. - Initiated investigation of methods to engineer communities of microorganisms with reliably controlled population dynamics. - Began to explore methods to rationally engineer functional microbial communities. ***FY 2016 Plans:*** - Demonstrate methods to engineer organisms that are functionally stable over time in changing growth conditions. - Demonstrate methods to engineer complex communities of microorganisms with reliably controlled population dynamics.	8.849	12.080	10.235

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Demonstrate methods to rationally engineer functional microbial communities of increasing complexity. ***FY 2017 Plans:*** - 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.			
Title: Understanding Biological Complexity* ***Description:*** *Formerly Applying Biological Complexity at Scale Biological systems operate over an enormous range of spatial, physical, and temporal scales and span individual cells to multi-organism systems. This project 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 Plans:*** - Investigate predictive design rules and engineering approaches for integrated biosystems. - Initiate research into biological systems with reduced complexity to facilitate predictive design for biological engineering. - Research cross-scale biological system responses to varying stimuli to understand defining characteristics of dynamic states. - Investigate dynamics and thresholds for transgene stability/instability in systems of infectious disease vectors. ***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.	-	9.000	10.250
Title: Modeling and Forecasting of Social Dynamics (MFSD) ***Description:*** Exploiting prior work in the areas of social media and social networks in programs such as Social Media in Strategic Communication (SMISC) in this project and Graph-theoretical Research in Algorithm Performance & Hardware for Social networks (GRAPHS) in project CCS-02, the Modeling and Forecasting of Social Dynamics (MFSD) program will develop and	-	4.500	10.000

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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 2015	FY 2016	FY 2017
demonstrate modeling capabilities that anticipate changes in social systems. The U.S. military works with local populations in an effort to strengthen relationships and gain new allies for purposes of security cooperation, with successful engagement fundamental to meeting these objectives. Current approaches to engagement planning are more art than science and rigorous approaches for understanding the social dynamics of local populations are lacking. MFSD will address this need by developing and demonstrating analogical societal models that, while reduced in scope, preserve the key properties of full social systems while remaining amenable to simulation. MFSD will rigorously test and validate the resulting models and establish the limits to the predictive capability they provide. Social media and other computer-mediated communications provide an important opportunity both as drivers of social dynamics and as indicators of social attitudes. The techniques that MFSD creates will enable the U.S. military to engage more effectively with local populations. ***FY 2016 Plans:*** - Formulate analogues to human social systems that preserve key properties while remaining amenable to laboratory experimentation and computational simulation. ***FY 2017 Plans:*** - Build initial analogical-model-based simulations for social phenomena. - Develop techniques for testing models for social dynamics using real-world data including historical, current events, and social media and/or other online data. - Initiate development of a decision support tool for predicting the effectiveness of alternative engagement options.			
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. ***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.	-	-	7.500
Title: Decoding Neural Activity	-	-	6.100

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
Description: Decoding Neural Activity seeks to utilize measures of physiological state and neural intention to improve the performance of semi-autonomous and supervised machine learning systems. Through the integration of new techniques from computer science, mathematics, signal processing, and statistics, this effort will investigate new methods for combining physiological and environmental data to decode neural signals and communicate information to computational platforms. Research within this effort will include the generation of novel sensors as well as improved architecture, mathematics, and procedures underlying algorithms and analysis. Successful research in this thrust will inform the development of tools to improve the performance of interfaces and communication between humans and machines. Potential applications range from learning systems and human-machine collaboration to assisted human operations and advanced manned-unmanned system teaming. ***FY 2017 Plans:*** - Begin to develop methods to integrate physiologically generated signals with automated computational systems. - Investigate architecture, mathematics, and procedures to improve analysis and interpretation of neural signals in real-time. - Explore methods to improve signal processing for direct measurements of physiological and neurophysiological state.			
Title: Vanishing Programmable Resources (VAPR) ***Description:*** The Vanishing Programmable Resources (VAPR) program will create microelectronic systems capable of physically disappearing (either in whole or in part) in a controlled, triggerable manner. The program will develop and establish an initial set of materials and components along with integration and manufacturing capabilities to undergird a fundamentally new class of electronics defined by their performance and transience. These transient electronics ideally should perform in a manner comparable to Commercial Off-The-Shelf (COTS) systems, but with limited device persistence that can be programmed, adjusted in real-time, triggered, and/or sensitive to the deployment environment. Applications include sensors for conventional indoor/ outdoor environments (buildings, transportation, and materiel), environmental monitoring over large areas, and simplified diagnosis, treatment, and health monitoring in the field. VAPR will explore transience characteristics of electronic devices and materials as well as build out an initial capability to make transient electronics a deployable technology for the DoD and Nation. The technological capability developed through VAPR will be demonstrated through a final test vehicle of a transient sensor with RF link. A basis set of transient materials and electronic components with sufficient electronic and transience performance is needed to realize transient electronic systems for environmental sensing and biomedical applications. Research and development of novel materials for implementing basic transient electronic components (actives and passives), power supply strategies, substrates and encapsulants as well as development of modes and triggers for transience will form the core of fundamental research activities. Transient components and devices developed in this technical area will form the basis for advanced functional circuit blocks and test systems to be developed in PE 0602716E, Project ELT-01.	1.815	1.522	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
FY 2015 Accomplishments: - Established an initial set of electronic materials that exhibit a useful combination of transience and the necessary physical characteristics required for sufficient electronic performance. - Demonstrated glass substrates that shatter into vanishingly small pieces when triggered with an electrical current. - Demonstrated bonding of electronic circuits to transience glass substrates and transferred glass fracturing into these electronic circuits to form vanishing electronic devices. - Demonstrated transient polymer packaging with sufficient stiffness to support electronic assemblies. - Demonstrated rapid transience of high stiffness transient polymer packaging. - Began developing and refining device modeling tools that incorporate transience effects. ***FY 2016 Plans:*** - Develop polymers with desired mechanical strength and transient characteristics for VAPR sensors. - Elucidate and model the physical mechanisms governing materials/device transience. - Integrate transient components of a sensor with RF link system (acoustic sensor, silicon RF and digital circuits, and on-board power) to demonstrate triggered disappearance of an integrated system.			
Title: Social Media in Strategic Communication (SMISC) ***Description:*** The Social Media in Strategic Communication (SMISC) program developed techniques to detect, classify, measure, and track the formation, development, and spread of ideas and concepts (memes) in social media. These techniques will provide warfighters and intelligence analysts with indications and warnings of adversary efforts to propagate purposefully deceptive messaging and misinformation. Social media creates vulnerabilities that can be exploited to threaten national security and has become a key operating environment for a broad range of extremists. SMISC developed technology and a new supporting foundational science of social networks will enable warfighters to defend against malevolent use of social media and to counter extremist influence operations. ***FY 2015 Accomplishments:*** - Integrated algorithms for meme detection and tracking with algorithms for detecting deception, persuasion, and influence operations. - Developed high fidelity diffusion models for messages, narratives, and information across social media. - Refined algorithms for sentiment analysis of content on developing social multi-media platforms.	6.076	-	-
Accomplishments/Planned Programs Subtotals	30.740	38.390	53.070

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** TRS-01 / *TRANSFORMATIVE SCIENCES*

C. Other Program Funding Summary ($ in Millions)

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: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	59.341	56.544	57.791	-	57.791	65.685	67.882	66.456	66.456	-	-
MED-01: *BASIC OPERATIONAL MEDICAL SCIENCE*	-	59.341	56.544	57.791	-	57.791	65.685	67.882	66.456	66.456	-	-

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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	60.757	56.544	62.807	-	62.807
Current President's Budget	59.341	56.544	57.791	-	57.791
Total Adjustments	-1.416	0.000	-5.016	-	-5.016
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.416	0.000			
• TotalOtherAdjustments	-	-	-5.016	-	-5.016

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

	FY 2015	FY 2016
Project: MED-01: *BASIC OPERATIONAL MEDICAL SCIENCE*		
Congressional Add: *Basic Research Congressional Add*	10.909	-
Congressional Add Subtotals for Project: MED-01	10.909	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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*

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2015	FY 2016
Congressional Add Totals for all Projects	10.909	-

Change Summary Explanation

FY 2015: Decrease reflects the SBIR/STTR transfer.
FY 2016: N/A
FY 2017: Decrease reflects completion of several Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT) program milestones.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT) ***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 2015 Accomplishments:*** - Collected serum from ill, convalescent, or immunized humans and identified two or more antibodies that in combination may provide disease-specific protection. - Demonstrated ability to administer nucleic acid encoding multiple antibodies to protect against existing, unmet, clinical targets; emerging global infectious diseases; and known, engineered biothreats. - Demonstrated onset of protection within hours after delivery and duration of therapeutic response greater than IV administered antibodies. - Demonstrated response and duration of antibody-encoding nucleic acid constructs similar to that conferred by administration of preformed antibodies against infectious disease in a large animal model.	48.432	33.400	16.566

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
- Demonstrated optimized, high sensitivity assay methods for protein and nucleic acid biomarkers, suitable for incorporation in deployable devices. - Demonstrated advanced materials properties and incorporation of developed materials into disposable assay formats. - Demonstrated advanced methods for reagent stabilization and delivery for assays developed for deployable devices. - Demonstrated sample preparation methods in conjunction with developed assays and quantified performance metrics. - Demonstrated performance of developed assays using advance no/low power microfluidic methods. - Measured performance of developed diagnostic methods and demonstrated capability to measure clinically relevant analyte levels in appropriate biospecimen matrices. - Demonstrated in mammalian cells the function of a synthetic circuit that can control the timing and level of expression of a protein when expressed from an RNA-based expression vector. - Demonstrated in mammalian cells the function of a synthetic circuit that can integrate at least two physiological signals associated with a change in health status and respond to at least two exogenously added small molecules, and respond with a targeted change in cell state. - Demonstrated the ability to generate a synthetic antibody via continuous evolution that can specifically bind to a defined target in mammalian cells. - Investigated non-traditional approaches to treating infectious diseases. ***FY 2016 Plans:*** - Establish biodistribution maps in appropriate models resulting from varied delivery methods, formulations, and devices relevant to nucleic acid constructs for antibody production. - Demonstrate protection conferred by delivery of nucleic acid constructs encoding two or more antibodies in validated infectious disease animal model. - Submit Investigational New Drug (IND) application for transient nucleic acid-based formats against infectious disease. - Demonstrate increased protective response and duration of antibody-encoding nucleic acid constructs against infectious disease in a large animal model. - Conduct IND-enabling non-clinical studies of DNA-monoclonal antibody (mAb) candidate. - Deliver high-sensitivity assay methods for protein and nucleic acid biomarkers for incorporation into deployable devices. - Deliver advanced materials for incorporation into disposable assay formats. - Deliver advanced methods for reagent stabilization and delivery for incorporation into deployable devices. - Deliver sample preparation methods for incorporation into deployable devices. - Demonstrate 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.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
- Demonstrate efficacy of gene encoded antibodies in a human clinical trial. - 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 Plans:*** - Initiate studies to enhance understanding of biological adaptability in response to external pressures. - Investigate predatory bacteria effectiveness against pathogens of interest. - Initiate studies of the relevant underlying mechanisms of bacterial predation. - Identify fundamental mechanisms that control the transition between unicellular and multicellular function. - Research basic science processes by which bacteria grow and spread throughout a community. - Investigate 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.	-	10.103	13.575
Title: Analysis and Adaptation of Human Resilience ***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. Projects 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	-	13.041	18.100

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
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. Projects within this program may enable discovery of novel methods to optimize human health against infectious diseases caused by multi-drug resistant pathogens. ***FY 2016 Plans:*** - Develop animal testbeds to evaluate human-relevant infection across multiple resilient species. - Assess diagnostic technologies that can rapidly detect pathogen load and characterize the different stages of infection in multiple animal species. - Analyze experimental results and bioinformatics datasets to discover key markers of tolerance. - Develop 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.			
Title: Outpacing Infectious Disease ***Description:*** The Outpacing Infectious Disease thrust will investigate fundamental methods for using biology as a technology to create adaptive therapeutic response mechanisms to outpace viruses and bacteria. Today, protective measures such as antibiotics and vaccines are often circumvented by fast-mutating viruses and bacteria that evolve to create new methods for pathogenicity. New approaches, such as enabling co-evolution and co-transmission of newly developed therapeutics to ultimately outcompete the pathogen, are needed to utilize the power of evolution in vaccine and antibiotic design. Key advances expected from this research include identifying methods to discover and develop new classes of dynamic therapeutics for fast-mutating viruses and antibiotic-resistant bacteria, as well as recurrent chronic diseases. This approach represents a significant departure from conventional antibacterial and 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 disease. ***FY 2017 Plans:*** - Investigate approaches to design and build pathogen-derived therapeutics that control disease by interfering with the pathogen via dynamic mechanisms.	-	-	9.550

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
- Assess the safety, efficacy, and transmissibility of novel co-evolving therapeutics using in vitro models. - Initiate design of computational models to assess host-disease-therapeutic dynamics at the individual and population levels.			
Accomplishments/Planned Programs Subtotals	48.432	56.544	57.791

	FY 2015	FY 2016
Congressional Add: Basic Research Congressional Add ***FY 2015 Accomplishments:*** Supports increased efforts in basic research that engage a wider set of universities and commercial research communities.	10.909	-
Congressional Adds Subtotals	10.909	-

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

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

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E *I BIOMEDICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	164.589	114.262	115.213	-	115.213	109.817	120.852	116.651	116.651	-	-
BT-01: *BIOMEDICAL TECHNOLOGY*	-	164.589	114.262	115.213	-	115.213	109.817	120.852	116.651	116.651	-	-

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 and the capability to manufacture field-relevant pharmaceuticals in theater. New neural interface technologies will reliably extract information from the nervous system to enable control of the best 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 mild traumatic brain injury (mTBI). FY 2015 Biomedical Technology program funding includes 117.0 million of base funding and 47.5 million congressionally added funding including $45.0 million of Ebola emergency funding.

B. Program Change Summary ($ in Millions)	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	159.790	114.262	109.069	-	109.069
Current President's Budget	164.589	114.262	115.213	-	115.213
Total Adjustments	4.799	0.000	6.144	-	6.144
• 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	8.295	0.000			
• SBIR/STTR Transfer	-3.496	0.000			
• TotalOtherAdjustments	-	-	6.144	-	6.144

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2015	FY 2016
Project: BT-01: *BIOMEDICAL TECHNOLOGY*		
Congressional Add: *Ebola Response and Preparedness Congressional Add (Emergency Funds)*	45.000	-
Congressional Add: *Biomedical Congressional Add*	2.548	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E *I BIOMEDICAL TECHNOLOGY*

Congressional Add Details ($ in Millions, and Includes General Reductions)	**FY 2015**	**FY 2016**
Congressional Add Subtotals for Project: BT-01	47.548	-
Congressional Add Totals for all Projects	47.548	-

Change Summary Explanation

FY 2015: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2016: N/A
FY 2017: Increase reflects new focus areas in monitoring health and disease and human performance optimization.

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
Title: Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT)	27.000	22.700	13.441

Description: The overarching goal of the Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT) program is to increase our ability to rapidly respond to a disease or threat and improve individual readiness and total force health protection by providing centralized laboratory capabilities at non-tertiary care settings. ADEPT will focus on the development of Ribonucleic Acid (RNA)-based vaccines, potentially eliminating the time and labor required for traditional manufacture of a vaccine while at the same time improving efficacy. Additionally, ADEPT will develop methods to transiently deliver nucleic acids for vaccines and therapeutics, and kinetically control the timing and levels of gene expression so that these drugs will be safe and effective for use in healthy subjects. ADEPT will also focus on advanced development of key elements for simple-to-operate diagnostic devices. A companion basic research effort is budgeted in PE 0601117E, Project MED-01.

FY 2015 Accomplishments:
- Demonstrated the ability to control the time duration of therapeutic response to viral, bacterial, and/or antibiotic-resistant bacterial pathogens suitable for clinical use and rapid public health responses.
- Investigated targeted delivery of nucleic acid constructs to specific cell types.
- Demonstrated feasibility for controlling pharmacokinetics and immunity modulation components to enable a more potent and broader immune response to viral, bacterial, and/or antibiotic resistant bacterial pathogens.
- Developed designs for RNA-based vaccines to enable transition to human clinical trials.
- Developed designs for initial diagnostic device prototypes based on highest performing components.
- Produced first-generation, integrated diagnostic prototypes designed for relevance to physician office, remote clinic, and low-resourced settings.
- Measured quantitative performance of first-generation, integrated diagnostic device prototypes and determine modifications required for performance improvements.

FY 2016 Plans:

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Optimize formulation of transient nucleic acid formats for storage stability at room temperature for at least six months. - Demonstrate continuous production of nucleic acid formats for transient immunity to viral, bacterial, and/or antibiotic-resistant bacterial pathogens for population-scale use. - Incorporate device optimizations identified as a result of first-generation, integrated diagnostic device testing. - Produce integrated diagnostic device prototypes designed for relevance to physician office, remote clinic, and low-resourced settings. - Measure 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: Restoration of Brain Function Following Trauma ***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 2015 Accomplishments:*** - Identified commonalities of neural codes underlying memory formation. - Identified distinctions between neural codes underlying different classes of memories. - Identified expert memory codes for the formation of memory associations between pairs of elements (e.g., objects, locations, actions). - Initiated development of a portable computational device with integrated computational model of human memory formation. - Demonstrated task-specific improvement/restoration of memory performance in a memory task via hippocampal stimulation. ***FY 2016 Plans:*** - Refine computational model of memory toward distinguishing underlying neural activity related to forgotten memories in three categories and spatial and non-spatial associations. - Identify optimal stimulation parameters for improving performance on spatial memory tasks.	9.700	15.800	19.400

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Utilize 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. - Determine the long-term signatures underlying stimulation-induced memory restoration tasks. - Design, develop and validate 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.			
Title: Neuro-Adaptive Technology ***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 2015 Accomplishments:*** - Developed tests that activate key brain subnetworks for each functional domain. - Developed computer algorithms/programs to automatically merge elements of multimodal brain activity across time/space.	21.500	30.589	26.388

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E *I BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Created statistical computational models of brain activity and corresponding behavior to support the neurophysiology of new therapeutic systems. - Trained decoders on a subset of domains and cross-validated on novel scan, record, and stimulate data. - Developed hardware interface stability, biocompatibility, and motion correction for recording neural activity. - Demonstrated three-dimensional, single-cell-resolution acquisition of real-time brain activity in large volumes of neural tissue. - Submitted initial, novel devices for regulatory approval. ***FY 2016 Plans:*** - Develop and apply data co-registration and fusion methods for neural activity, wiring, and behavior. - Generate and annotate first intact neural tissue volumes to elucidate microstructure and connections in three dimensions. - Design algorithms for automatic cell identification and optical-signal estimation. - Elucidate neural circuit dynamics using structurally-informed network models. - Refine optical techniques for imaging large volumes of neural tissue. - Expand data curation architecture, databases, and analytical tools to distribute generated data to the neuroscience community. - Develop methods for automatically detecting and removing noise or contamination from datasets. - Deliver a hierarchical computational model of key brain networks that captures features relevant for psychiatric illness and its treatment. - Develop and refine neural state acquisition, classification, and control algorithms to support closed-loop control in an implantable neural device. - Characterize neural network plasticity during behavioral training. ***FY 2017 Plans:*** - 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.			
Title: Prosthetic Hand Proprioception & Touch Interfaces (HAPTIX) ***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	10.550	18.300	18.500

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
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 2015 Accomplishments:*** - Developed and demonstrated advanced algorithms to control prosthetic limbs using signals extracted from commercially available or newly developed electrodes. - Developed and demonstrated micro-stimulation interface technologies that provide reliable signals into the peripheral and/or central nervous system for closed-loop prosthetic control. - Performed safety and efficacy testing of novel implantable interface technology which capture motor control signals and provide electrical sensory stimulation through the peripheral nervous system. - Demonstrated bench-top functionality of next-generation peripheral interface technology. - Developed draft version of outcome metrics for quantifying effects of implantable and external system components on motor function, sensory function, pain, psychological health, and quality of life. - Developed unified virtual prosthesis environment to simulate limb motion and forces of interaction during object manipulation. ***FY 2016 Plans:*** - Integrate interface and electronic systems technology for use in human amputees to control and receive intuitive sensory feedback from a prosthetic device. - Demonstrate closed-loop control of a virtual prosthesis. - Perform safety and efficacy testing of HAPTIX system components to capture motor control signals and provide electrical sensory stimulation through the peripheral nervous system. - Demonstrate in vivo functionality of next-generation HAPTIX peripheral interface technology. - Finalize HAPTIX system prosthetic limb technology, complete sensorization, and begin manufacturing of devices. - Implement draft version of outcome metrics for quantifying effects of HAPTIX technology and begin validation studies. ***FY 2017 Plans:*** - Initiate functional validation of input/output signal transfer and wireless communication of power and data. - Conduct 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.			
Title: Tactical Biomedical Technologies	12.654	7.150	6.909

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
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 was the co-development of a materials-based agent(s) and delivery mechanism capable of hemostasis and wound control for non-compressible hemorrhage in the abdominal space, regardless of wound geometry or location within that space. This thrust also investigated non-invasive techniques and equipment to use laser energy to treat intracranial hemorrhage through the skull and tissues in a pre-surgical environment. Finally, in order to address logistical delays associated with delivering necessary therapeutics to the battlefield, this thrust 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 2015 Accomplishments:*** - Developed novel continuous flow crystallizer, miniaturized reactors, and chemically compatible pumps for integration into a bench scale end-to-end manufacturing platform for the following Active Pharmaceutical Ingredients (APIs): Diphenhydramine, Diazepam, Lidocaine, Fluoxetine, Ibuprofen, Atropine, Doxycycline, Salbutamol, Ciprofloxacin, Azithromycin, Rufinamide, Etomidate, Nicardipine, and Neostigmine. - Demonstrated continuous flow synthesis, crystallization, and formulation for Salbutamol, Ciprofloxacin, Azithromycin, Rufinamide, Etomidate, Nicardipine, and Neostigmine in an integrated manufacturing platform. - Engaged the Food and Drug Administration (FDA) for input on Process Analytical Technologies (PAT) and Current Good Manufacturing Process (cGMP) for Salbutamol, Ciprofloxacin, Azithromycin, Rufinamide, Etomidate, Nicardipine, and Neostigmine. - Developed novel cell-free protein synthesis techniques using miniaturized bioreactors and/or microfluidics technologies. - Demonstrated end-to-end manufacturing of two protein therapeutics in a miniaturized platform, including the integration of protein expression and purification processes. - Engaged the FDA for input on PAT and cGMP for protein therapeutics. - Tested prototype device during in vivo pre-clinical studies for treatment of intracranial hemorrhage using laser energy through skull and tissues, and engage with the FDA on design and execution of these studies to meet FDA requirements. ***FY 2016 Plans:*** - Develop continuous synthesis of Ciprofloxacin (from basic starting materials) and Lisinopril in miniaturized integrated manufacturing platform. - Demonstrate end-to-end manufacturing and solid formulation of Ciprofloxacin in miniaturized integrated manufacturing platform. - Design and develop cell-based and cell-free protein expression of four additional biologics out of Insulin, Factor VIIa, Interferon, Hepatitis B Surface Antigen, Tissue Plasminogen Activator, Granulocyte Colony-Stimulating Factor, and Rituxmab.			

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Optimize 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 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 and integrated platform.			
Title: Performance Optimization in Complex Environments ***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 Plans:*** - Initiate research on biological interfaces for enabling input-output of information. - Explore and identify scalable technologies for reading and writing biological signals. ***FY 2017 Plans:*** - Refine component technologies to increase scale of information input-output. - 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.	-	9.650	16.475
Title: Enhanced Monitoring of Health and Disease ***Description:*** The overarching goal of the Enhanced Monitoring of Health and Disease program is to leverage advanced data collection methods and capabilities to predict changes in health and spread of infectious disease from the individual to the	-	-	14.100

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
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:*** - Assess novel methods for multiplexed in vivo monitoring and wireless transmission of data related to disease biomarkers. - Collect biological samples to assess asymptomatic, symptomatic, and co-infection rates among a research cohort. - Identify key parameters of robust epidemiological models for predicting disease transmission. - Evaluate the predictive capability of dynamic, ensemble-based epidemiological models for disease forecasting.			
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 is to develop a portable device capable of controlling relevant components in the blood volume on clinically relevant time scales. Reaching this goal is expected to require significant advances 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 envisioned device would 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 further develops and applies existing component technologies and then integrates these to create a complete blood purification system for use in the treatment of sepsis. Included in this effort will be 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 2015 Accomplishments:***	19.492	5.073	-

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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 2015	FY 2016	FY 2017
- Manufactured a breadboard device that integrates label-free separation technologies, high-flow fluidic architectures, and non-thrombogenic coatings for testing. - Evaluated the efficacy of the label-free separation technologies in a small-animal model. - Refined the breadboard device design based on animal testing results to inform development of a standalone benchtop integrated prototype device. - Established a clinically relevant model of sepsis in a large animal model in order to validate efficacy of separation technologies at removing pathogens and other sepsis mediators. - Performed biocompatibility studies of each component filter in the device to ensure safety in the integrated system. ***FY 2016 Plans:*** - Complete fabrication of the first generation of integrated DLT device prototypes. - Complete safety studies of the integrated DLT device in a large-animal model. - Initiate safety studies focused on pathogen removal in large-animal model.			
Title: Warrior Web ***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 will mitigate that impact by developing an adaptive, quasi-active, joint support sub-system that can be integrated into current soldier systems. Because this sub-system will be compliant and transparent to the user, it will reduce the injuries sustained by warfighters while allowing them to maintain performance. Success in this program will require 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 is planned to weigh no more than 9kg and require no more than 100W of external power. Allowing the warfighter to perform missions with reduced risk of injuries will have immediate effects on mission readiness, soldier survivability, mission performance, and the long-term health of our veterans. ***FY 2015 Accomplishments:*** - Conducted preliminary review of Warrior Web designs and refined approaches as necessary. - Finalized open source biomechanical models to be leveraged for the Warrior Web system evaluation. - Matured design of Warrior Web system and continued parallel technology development. - Conducted preliminary evaluation of prototype Warrior Web systems via Soldier tests in laboratory environment. ***FY 2016 Plans:*** - Revise full suit design and implementation based on laboratory evaluations. - Continue to evaluate prototype Warrior Web systems via Soldier tests in laboratory and field environments.	7.245	5.000	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
- Continue to pursue research and development of technologies to augment human performance and support rehabilitation.			
Title: Pathogen Defeat ***Description:*** Pathogens are well known for the high rate of mutation that enables them to escape drug therapies and primary or secondary immune responses. The Pathogen Defeat thrust area provided capabilities to predict emerging threats and the evolution of resistance of pathogens to medical countermeasures. Pathogen Defeat focused not only on known pathogens but also newly emerging pathogens and future evolution of mutations in these pathogens, allowing pre-emptive preparation of vaccine and therapy countermeasures. ***FY 2015 Accomplishments:*** - Tested predictive capabilities of trajectories to clinical viral isolates in evolution platform. - Elucidated mechanisms to explain viral escape to different pressures. - Rapidly evolved virus strains in avian cells to select vaccine candidates with antigenic similarities. - Performed objective assessment of hand-held devices for detecting biothreats and clinically-relevant pathogens.	8.900	-	-
Accomplishments/Planned Programs Subtotals	117.041	114.262	115.213

	FY 2015	**FY 2016**
Congressional Add: Ebola Response and Preparedness Congressional Add (Emergency Funds) ***FY 2015 Accomplishments:*** This program focused on the development of Ebola antibodies, vaccines, and diagnostics to enable a more rapid response to this outbreak and increase preparedness for response to future epidemics. This research utilized earlier investments by DARPA that explored technologies to discover, optimize, and deliver antibodies as a means to provide fast-acting protection against infectious diseases. A key component of this program was not only identifying effective antibodies to treat and prevent disease, but also defining and developing the antibody gene blueprint for transfer and production of vaccines. The Ebola Response and Preparedness Congressional Add is non-OCO emergency funding. - Conducted dose escalation study for encoded Ebola vaccine in human safety trial. - Demonstrated rapid discovery of potent antibodies from human Ebola survivors. - Evaluated protective efficacy of encoded Ebola antibodies in small and large animal models. - Tested protective efficacy of encoded Ebola vaccine in small and large animal models. - Validated cell-free production of nucleic acid-encoded antibody and vaccine formulations.	45.000	-
Congressional Add: Biomedical Congressional Add	2.548	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

	FY 2015	FY 2016
FY 2015 Accomplishments: This effort furthered the development of restorative products and technologies as alternatives to amputation.		
Congressional Adds Subtotals	47.548	-

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

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

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	315.923	341.358	353.635	-	353.635	353.925	359.959	344.530	354.091	-	-
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	32.437	38.494	42.459	-	42.459	55.179	60.075	44.413	58.413	-	-
IT-03: *INFORMATION ASSURANCE AND SURVIVABILITY*	-	170.959	202.252	255.137	-	255.137	257.172	258.028	258.362	258.923	-	-
IT-04: *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*	-	48.636	60.948	56.039	-	56.039	41.574	41.856	41.755	36.755	-	-
IT-05: *CYBER TECHNOLOGY*	-	63.891	39.664	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 is developing the necessary computing hardware and the associated software technology base required to support future critical national security needs for computationally-intensive and data-intensive applications. These technologies will lead to new multi-generation product lines of commercially viable, sustainable computing systems for a broad spectrum of scientific and engineering applications; it will include supercomputer and embedded computing 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; and to respond intelligently to new and unforeseen events. Enabling computing systems in this manner is of critical importance because sensor, information, and communication systems generate data at rates beyond which humans can assimilate, understand, and act. Incorporating these technologies in military systems will enable warfighters to make better decisions in complex, time-critical, battlefield environments; intelligence analysts to make sense of massive, incomplete, and contradictory information; and unmanned systems to operate safely with high degrees of autonomy.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602303E I *INFORMATION & COMMUNICATIONS TECHNOLOGY*

The Cyber Technology project develops 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 will ensure DoD net-centric capabilities survive adversary cyber attacks and will enable new cyber-warfighting capabilities.

B. Program Change Summary ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017 Base**	**FY 2017 OCO**	**FY 2017 Total**
Previous President's Budget	324.407	356.358	364.076	-	364.076
Current President's Budget	315.923	341.358	353.635	-	353.635
Total Adjustments	-8.484	-15.000	-10.441	-	-10.441
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	-15.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	1.831	0.000			
• SBIR/STTR Transfer	-10.315	0.000			
• TotalOtherAdjustments	-	-	-10.441	-	-10.441

Change Summary Explanation

FY 2015: Decrease reflects reprogrammings offset by the SBIR/STTR transfer.

FY 2016: Decrease reflects congressional reduction.

FY 2017: Decrease reflects completion of the Power Efficiency Revolution For Embedded Computing Technologies (PERFECT) and Robust Automatic Translation of Speech (RATS) programs.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	32.437	38.494	42.459	-	42.459	55.179	60.075	44.413	58.413	-	-

A. Mission Description and Budget Item Justification

The High Productivity, High-Performance Responsive Architectures project is developing high-productivity, high-performance computer hardware and the associated software technology base required to support future critical national security needs for computationally-intensive and data-intensive applications. These technologies will lead to new multi-generation product lines of commercially viable, sustainable computing systems for a broad spectrum of scientific and engineering applications; it will include both supercomputer and embedded computing systems. The goal will be to create not just larger computing platforms, but to extract information out of large and chaotic data sets efficiently. One of the major challenges currently facing the DoD is the prohibitively high cost, time, and expertise required to build complex computing systems including software and hardware. Powerful new approaches and tools are needed to enable the rapid and efficient production of new software, including software that can be easily changed to address new requirements and can adjust dynamically to platform and environmental perturbations. The project will ensure accessibility and usability to a wide range of application developers, not just computational science experts.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Complexity Management Hardware	7.500	11.194	10.000
Description: The battlefield of the future will have more data generators and sensors to provide information required for successful combat operations. With networked sensors, the variety and complexity of the information streams will be even further extended. The Complexity Management Hardware program will develop silicon designs which help alleviate the complexity inherent in next generation systems. These systems will have increasingly large data sets generated by their own multidomain sensors (such as RF and Electro-Optical/Infrared (EO/IR) payloads) as well as potentially new inputs from external sensors. With current programming approaches, there are laborious coding requirements needed to accommodate new data streams. Additionally, the context provided by these data sets is ever changing, and it is imperative for the integrated electronics to adapt to new information without a prolonged programming cycle. Providing contextual cues for processing data streams will alleviate the fusion challenges that are currently faced, and which stress networked battlefield systems. As opposed to the intuition and future-proofing that is required at the programming stage of a current system, the silicon circuit of the future will be able to use contextual cues to adapt accordingly to new information as it is provided. The applied research aspects of this program will investigate circuit design which can exploit the algorithms showing benefit for complexity management. This will entail various sparse versus dense data manipulations with hardware implementations catered			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
to both types of data. The program will show hardware implementations that gracefully handle multiple data streams and limit the programming burden for a complex scenario. Basic research efforts are funded in PE 0601101E, Project CCS-02. ***FY 2015 Accomplishments:*** - Designed complexity management processor algorithm and benchmark tests for object recognition in still images and action recognition in video. - Demonstrated critical features of algorithm including ability to learn and adapt while operating. - Quantified impact of using low precision, sparse network connectivity on accuracy of results. ***FY 2016 Plans:*** - Design transistor level circuits implementing the complexity management algorithms. - Demonstrate the ability to manage multiple data streams with interlaced information. - Create initial hardware verification of concepts for both sparse and hardware demonstrations. ***FY 2017 Plans:*** - Compare various algorithms ability to manage complex data sets. - Quantify the benefits of various architecture approaches to management of large data streams when overlaid with contextual information. - Translate the initial algorithms to high level circuit implementations to show the power and processing requirements.			
Title: Power Efficiency Revolution For Embedded Computing Technologies (PERFECT) ***Description:*** The Power Efficiency Revolution For Embedded Computing Technologies (PERFECT) program will provide the technologies and techniques to overcome the power efficiency barriers which currently constrain embedded computing systems capabilities and limit the potential of future embedded systems. The warfighting problem this program will solve is the inability to process future real time data streams within real-world embedded system power constraints. This is a challenge for embedded applications, from Intelligence, Surveillance and Reconnaissance (ISR) systems on unmanned air vehicles through combat and control systems on submarines. The PERFECT program will overcome processing power efficiency limitations by developing approaches including near threshold voltage operation, massive and heterogeneous processing concurrency, new architecture concepts, and hardware and software approaches to address system resiliency, combined with software approaches to effectively utilize resulting system concurrency and optimized data placement to provide the required embedded system processing power efficiency. The remaining efforts under the PERFECT program will emphasize the implementation of near threshold and specialization approaches to address processing efficiency. ***FY 2015 Accomplishments:***	24.937	17.800	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Incorporated test chip results - circuit, architecture, communication, power management, 3D - into design optimizations and simulation refinements for continuing architectural development efforts. - Developed compiler algorithms supporting communication-avoiding optimization, concepts for optimizing parallel codes, and programming language-based auto-tuning. - Delivered system-level integrated analytical modeling methodology and software analysis toolset for cross-layer, energy-constrained resilience optimization, processor, memory, and energy-reliability trade-offs. - Publically released new hardware description language and modeling/simulation infrastructure incorporating the evaluation and development of algorithms, specializers, hardware architectures, and resiliency techniques. ***FY 2016 Plans:*** - Select implementation and transition targets. Establish a focused subset of PERFECT teams' technologies to most effectively support target requirements. - Integrate our modeling and evaluation environment by combining separate optimization tools for power, communication avoidance, and resiliency. This will provide detailed trade-off analyses for a range of (1) ISR kernels, (2) PERFECT hardware targets, and (3) problem instance sizes. This will support 20X power savings, while respecting resiliency requirements, relative to classical application implementations. - Demonstrate High Level Source-to-Source transformation targeting PERFECT program specialization simulators. Generate optimized/vectorized code exploiting explicit memory movement and dynamic voltage and frequency control for performance efficiency. These will be demonstrated on ISR kernels and convolutional neural networks. - Demonstrate near memory fast Fourier transform accelerator supporting synthetic aperture radar and space-time adaptive processing using PERFECT architecture simulator. - Fabricate 14nm (Global Foundry) test chips to measure ultra low voltage Static random-access memory implementations. Anticipated results include a functional voltage of 0.3 Volts, and a 3x access time improvement versus conventional approaches. - Demonstrate the benefits of specialization using the PERFECT Vision Chip by emulating the execution of major vision kernels with the expectation to attain peak efficiencies.			
Title: Portable AnaLyticS (PALS)* ***Description:*** *Formerly Scalable Optical Nodes for Networked Edge Traversal (SONNET) Graph analytics on large data sets is currently performed on leadership-class supercomputers that are designed for other purposes. These machines are required because they have the memory capacity required for large graph problems, but the ability to efficiently move data to and effectively utilize compute resources is limited, resulting in extremely low compute efficiency. Computationally, graph analysis is characterized by many short, random accesses to memory which is inefficient on current	-	3.500	6.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
systems that are optimized for regular, predictable access. The movement of data between memory and processors now requires more time and energy than the logical operations themselves. This is the result of generations of systems that architecturally separate computing/data manipulation and main data storage. Large systems have shown utilization (percentage of system peak throughput capability used) drop from as high as 90% to in the order of 2% due to the data patterns for different applications. To resolve this problem, the PALS program will develop technologies, architectures, and software approaches that move critical data processing kernels and critical data organization operations adjacent to the memory itself, rather than at physically distant general computing nodes, addressing data latency, overall computational performance and power for critical data intensive elements of an application. The PALS approach is not to physically or functionally move processing entirely to the memory, but rather to move specific, critical data intensive components of an application to the data. The result will dramatically improve performance for data intensive applications, by off-loading the main processor of data-intensive operations, and enabling data security operations at the memory itself. This will be accomplished by utilizing industry advances in 3D packaging, particularly the bandwidth, latency and power advances being developed in 3D memory stacks; new software approaches for data management; investigating alternative data movement technologies such as co-designing processor and photonic hardware, exploiting the high bandwidth provided by silicon photonics. It will also include incorporation of domain specific logic for unique and asymmetric data-intensive DoD functional capabilities at all appropriate levels of a processing system's memory. The performance and efficiency will be transformational for data analytics for both big data and embedded data-intensive DoD applications and enable real-time analysis on dynamic graphs in the fields of cyber security, threat detection, and numerous others. ***FY 2016 Plans:*** - Identify common graph primitives that would accelerate the execution of DoD-specific applications. - Explore the applications benefitting from the unique architecture and whether unique hardware design allows for processors for unique military applications. - 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. ***FY 2017 Plans:*** - Develop domain specific concepts for functionality at the hierarchical levels of data storage levels, define logic and data orchestration capabilities at these layers of storage and processing, define customization versus programmability trade-offs, and define logic layer processing concepts. - Simulate performance of PALS for selected high value application specific and data-intensive applications. - Develop initial architectural trade-offs and implementation options.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Develop PALS based security concepts for data management in multi-security level environments.			
Title: Electronic Globalization ***Description:*** Approximately 66% of all installed semiconductor wafer capacity is in Asia. This creates a significant risk for the DoD as off-shore manufacturing of microelectronic components could introduce various vulnerabilities to DoD systems that utilize these non-U.S. fabricated electronic components. As the DoD is faced with this globalization reality, it is essential to prevent potential consequences such as reverse engineering, and the theft of U.S. intellectual property. New applied research technology enablement will be developed in the Electronics Globalization program to provide a means of assessing the impact of high stress upon Government Off-The-Shelf (GOTS) and Commercial Off-The-Shelf (COTS) components produced in conventional contemporary foundries. The potential application of these components in extreme stresses DoD systems and makes it even more important to understand the new physics mechanisms to be expected in these regimes. The extendibility of existing reliability models, and the calibration of new reliability models for components operated outside of typical use conditions will be studied. Further, the insight gained from understanding these impacts will inform the use of elevated stress burn-in and screening tools, potentially allowing shorter and more effective test times in the fabrication plant. ***FY 2016 Plans:*** - Improve the signal-to-noise ratio of the Navy system, allowing its use in a wider array of microelectronic parts. - Study high stress effects on conventionally fabricated COTS and GOTS electronic components. - Develop device physics models which accurately capture the reliability physics behavior of semiconductors operated at elevated voltage and temperature. ***FY 2017 Plans:*** - Continue prototype system enhancements to the laser scanning tools. - Continue to study high stress effects on conventionally-fabricated COTS and GOTS electronic components. - Characterize the physics models using the response of the fabricated devices to extreme stress associated with certain DoD applications as well as accelerated life stress testing and evaluation. - Complete the development of shorter, more effective reliability screens and burn-in testing using higher stress test conditions.	-	4.000	4.000
Title: tactical CONtext EXtraction (CONEX) ***Description:*** Enriching a primary data stream with contextual information (i.e., the circumstances or facts such as who, what, and where that surround a particular event) can be accomplished by fusing data from multiple sensors. For this task, modern systems rely heavily on man-made reference signals, such as Global Positioning Systems (GPS), and preprogrammed algorithms with limited adaptability. Object recognition using Deep Learning and related approaches has been demonstrated, but these methods	-	-	6.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
require significant offline training. The tactical CONtext EXtraction (CONEX) program will develop compact sensors and adaptive processors for extracting contextual information from resource-constrained environments. CONEX sensors will collect information from the landscape and natural sources, such as the relative position of stars, to supplement inertial measurement systems and other sensor feeds in GPS-denied areas. CONEX processors will contain embedded real-time learning algorithms that operate over multiple timescales. These adaptive methods efficiently capture complex spatial and temporal structure in noisy, ambiguous data streams that are beyond the analysis capabilities of state-of-the-art signal/image processing systems. ***FY 2017 Plans:*** - Refine designs of integrated circuits that implement real-time learning algorithms. - Design compact, low-power CONEX sensors to support context accumulation in selected environments. - Demonstrate performance enhancement of novel content extraction algorithms and software. - Demonstrate basic functionality of prototype CONEX sensors.			
Title: Removing Barriers to Hardware (REBHAR) ***Description:*** Small software companies are a dynamic force in the U.S. economy because they face very low barriers to innovation. Anyone can code applications for established mobile or cloud platforms and leverage the tremendous infrastructure built by larger companies to quickly access potential customers. However, commercial hardware innovations for advanced integrated circuits and Micro-Electro-Mechanical Systems (MEMS) sensors face costly obstacles that impede progress outside of large corporations. Smaller businesses generally do not have the budget or sales volume to access the latest design software, verification tools and fabrication processes. The smaller DoD market for hardware amplifies these problems for delivering revolutionary military components. The Removing Barriers to Hardware (REBHAR) program will develop methods to facilitate hardware innovation for defense applications. The objective of the REBHAR program is to establish relationships with commercial companies to gain access to proven processes, to explore the possibilities of open source hardware, and to develop an aftermarket customization strategy to economically adapt commercial chips to specific military needs. ***FY 2017 Plans:*** - Explore the concept of open source design kits and open source hardware development cycles. - Demonstrate methods for aftermarket customization of commercial integrated circuits for select defense applications. - Demonstrate circuits based on open source design kits.	-	-	6.000
Title: Spectrum Grand Challenge ***Description:*** The objective of the Spectrum Grand Challenge is for participants to develop wireless communications networks which can learn to cohabitate and share the same Radio Frequency (RF) spectrum as other networks without preplanning or co-	-	2.000	10.459

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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 2015	FY 2016	FY 2017
design of the technologies. Access to spectrum is critical to many modern sectors: military, commercial, infrastructure, public-safety, disaster recovery, and many more. Spectrum however is treated as a scarce resource typically assigned to exclusive-use licenses. These approaches still rely on exclusive use of the spectrum by only a single network. In order to meet growing spectrum demands networks must be able to dynamically adapt their use of the spectrum as needs and as spectrum conditions change, autonomously determining when, where, and how spectrum should be used. Spectrum Grand Challenge solutions will survey their environment, learn to morph their configuration to suit both their needs and others, and employ interference coping and exploitation techniques to make more efficient use of the RF spectrum. The Spectrum Grand Challenge will develop the world's first large-scale spectrum testbed to test participants in realistic emulated conditions. The test conditions and qualification metrics developed will thoroughly vet solutions, and ultimately serve as the basis for certification of an envisioned new class of shared spectrum technology which does not rely on exclusive use of the spectrum. This program complements spectrum access and wireless communications work in PE 0603760E, Project CCC-02. ***FY 2016 Plans:*** - Define Spectrum Grand Challenge rules governing eligibility as well how the competition will be conducted and scored. ***FY 2017 Plans:*** - Design and build out large-scale spectrum testbed for use in the preliminary competition of the Spectrum Grand Challenge. - Hold qualifying event to select field of participants. - Hold preliminary competition in an emulated RF environment using spectrum sharing testbed.			
Accomplishments/Planned Programs Subtotals	32.437	38.494	42.459

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *INFORMATION ASSURANCE AND SURVIVABILITY*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
IT-03: *INFORMATION ASSURANCE AND SURVIVABILITY*	-	170.959	202.252	255.137	-	255.137	257.172	258.028	258.362	258.923	-	-

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 benefit other projects within this program element as well as projects in the Command, Control, and Communications program element (PE 0603760E), the Network-Centric Warfare Technology program element (PE 0603766E), the Sensor Technology program element (PE 0603767E), and other projects that require secure, survivable, network-centric information systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT)	11.500	22.000	29.938
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 (middleboxes) 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 collaboration with and transitioned to operational commands. ***FY 2015 Accomplishments:*** - Formulated a distributed architecture for reliable communications over high-speed wide-area networks that have been degraded by cyber attack, misconfiguration, or hardware/software failure. - Introduced techniques to sense and respond rapidly to network failures and attacks by dynamically adapting protocols utilized to exchange packets among hosts. - Created an initial wide-area network testbed enabling joint experimentation and demonstration of components and systems among program performers. ***FY 2016 Plans:***			

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop 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. - Demonstrate performance at the component and subsystem levels, to include real-time network analytics, holistic decision systems, and dynamically configurable protocol stacks. - Assess EdgeCT component and system designs for potential weaknesses, vulnerabilities, and countermeasures associated with cyber attacks against network infrastructure, or against EdgeCT systems themselves. - Initiate development of software prototypes suitable for laboratory experimentation with operational commands. - 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. ***FY 2017 Plans:*** - Demonstrate and evaluate system prototypes against program metrics to verify adequate performance for cumulative network utility, recovery time, and network overhead. - Increase the number of enclaves and total application data flows that can be accommodated during real-time operation. - Incorporate military applications, such as Command and Control (C2) software systems, into system demonstrations. - Extend usage and testing scenarios to include multiple forms of simultaneous failures and cyber attacks within the wide area network.			
Title: Cyber Fault-tolerant Attack Recovery (CFAR) ***Description:*** The Cyber Fault-tolerant Attack Recovery (CFAR) program is developing novel architectures to achieve cyber fault-tolerance with commodity computing technologies. Current approaches to handling cyber-induced faults in mission-critical systems are inadequate, as perimeter defenses wrapped around vulnerable monocultures do not scale, while zero-day exploits evade signature-based defenses. 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 guarantee differences in behavior under attack. The resulting CFAR-enabled computing systems will quickly detect deviations in processing elements at attack onset and rapidly reboot to restore affected services. ***FY 2015 Accomplishments:*** - Formulated a novel architecture that can achieve cyber fault-tolerance with commodity computing technologies without requiring changes to the system concept of operations. - Developed initial techniques for detecting differences across functionally replicated systems. - Developed initial techniques for producing novel compiled software variants that behave differently under attack. ***FY 2016 Plans:***	10.500	20.149	27.494

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Demonstrate functionally replicated systems and novel variants that provide performance close to optimal and exhibit sufficient variability to guarantee differences in behavior under attack. - Implement and test techniques for quickly detecting differences across replicated systems. - Implement and evaluate alternative architectures for achieving cyber fault-tolerance for mission-critical military applications with commodity computing technologies. - Work with potential transition sponsors to evaluate military computing systems as candidates for technology refresh with CFAR technologies. ***FY 2017 Plans:*** - Create variants from binary code, which will enable the technology to protect systems for which source code is not readily available. - Develop methods to produce mathematical proofs of semantic equivalence across variants, which will contribute to assurance cases that systems protected with CFAR technology behave identically to the original unprotected systems. - Develop robust cyber fault-tolerant models that, unlike conventional approaches to physical fault tolerance, handle the highly correlated and frequent faults that may result from a cyber-attack. - Demonstrate proof-of-concept on a representative mission system, showing that the system behaves identically to the original while providing protection and rapid recovery from cyber attacks.			
Title: Supply Chain Hardware Integrity for Electronics Defense (SHIELD) ***Description:*** Counterfeit electronic components compromise business as well as defense systems, and pose a threat to the integrity and reliability of DoD systems. Detection of counterfeit components by current means is expensive, time-consuming, and of limited effectiveness. Maintaining complete control of the supply chain using administrative controls incurs substantial costs and has exhibited limited effectiveness. Current methods of detection involve a wide variety of techniques ranging from functional testing to physical inspections which may still miss certain classes of counterfeits. There have also been attempts by the semiconductor market to protect electronic components through the use of technology embedded in the component or its packaging. However, most of these methods are specific to a manufacturer's component and as such address only those issues critical to that manufacturer. Some methods can be circumvented, or require slow, expensive, off-site forensic analysis to verify authenticity. The Supply Chain Hardware Integrity for Electronics Defense (SHIELD) program will develop a technology capable of confirming, at any time and place, the authenticity of trusted parts, even after they have transited a complex global supply chain. SHIELD will prevent counterfeit component substitution by incorporating a small, inexpensive additional silicon chip ("dielet") within the Integrated Circuit (IC) package. The dielet will provide a unique and encrypted ID as well as anti-tamper features. The	17.750	21.000	24.500

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
microscopic-size dielet embedded in the electronic component packaging will enable verification of a chip's identity from very close proximity. ***FY 2015 Accomplishments:*** - Refined design specifications and technical requirements for the SHIELD dielet, including Advanced Encryption Standard counter with Cipher Block Chaining Message Authentication Code (AES CCM) as the target encryption protocol. - Developed behavioral models for dielet power and communications to support preliminary design efforts. - Manufactured "surrogate" dielets with the dimensions and form factor of the SHIELD design for performers to develop package insertion methods and fragility testing. - Designed and manufactured hardware test sites to demonstrate proof of concept for key dielet technologies (sensors, power, communications, encryption, dielet fragility). ***FY 2016 Plans:*** - Refine designs based on measured results from test site hardware. Scale proof-of-concept work done at less advanced design nodes to the 40 nanometer and 14 nanometer target design nodes for SHIELD. - Design and manufacture hardware test sites to demonstrate second pass improvements for key dielet technologies. - Develop transaction model for reader-to-dielet interrogation. - Select best-fit Phase 1 technologies for inclusion on Phase 2 dielet designs, based on validated hardware measurements and objective analysis of design compatibility. - Refine dielet singulation, test and insertion methodology and fragility design based on mechanical testing of surrogate dielets. ***FY 2017 Plans:*** - Design and manufacture prototype SHIELD dielets, integrating best-fit technologies selected during Phase 1. - Implement dielet singulation method for wafers after manufacture. - 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 Phase 3 testing.			
Title: Brandeis* ***Description:*** *Previously Adaptable Information Access and Control (AIAC) 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. 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	7.593	17.600	25.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
partners, and other stakeholders. The Brandeis program will develop the technical means to protect the private and proprietary information of individuals and enterprises. Brandeis will break the tension between (a) maintaining privacy and (b) being able to tap into the huge value of data. Rather than having to balance between them, Brandeis aims to build a third option: enabling safe and predictable sharing of data in which privacy is preserved. The Brandeis program is timely due to recent progress on techniques such as homomorphic encryption, secure multiparty computation, and differential privacy. To facilitate deployment, Brandeis technologies will be designed to work with the virtualization, cloud computing, and software-defined networking technologies now widely used in both civilian and military environments. ***FY 2015 Accomplishments:*** - Formulated technical approaches to data privacy through secure multiparty computation, secure database queries, differential privacy and remote attestation of protected computing environments. - Identified canonical privacy use cases on which to evaluate candidate privacy technologies. - Conceptualized prototype evaluation platforms and metrics/analysis tools on which privacy technologies can be tested and metrics computed to quantify the privacy benefits. ***FY 2016 Plans:*** - Implement secure multiparty computation, secure database queries, differential privacy and remote attestation techniques in initial prototypes suitable for integration on commodity cloud infrastructures. - Develop prototype evaluation platform and metrics/analysis tools on which privacy technologies can be tested and metrics computed. - Initiate quantification of privacy benefits of privacy technologies in the context of canonical individual and enterprise privacy use cases. ***FY 2017 Plans:*** - Optimize privacy prototypes that implement secure multiparty computation, secure database queries, differential privacy and remote attestation techniques and test 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. - Initiate transition of techniques through integration on commercial, coalition partner, and military enterprise networks.			
Title: Rapid Attack Detection, Isolation and Characterization Systems (RADICS)* ***Description:*** *Previously Protecting Cyber Physical Infrastructure	7.525	17.513	24.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
The Rapid Attack Detection, Isolation and Characterization Systems (RADICS) program will create new technologies for maintaining the availability and integrity of critical U.S. cyber-physical infrastructure. This is a national security issue due to the near-ubiquitous use of computers to monitor and control U.S. civilian and military critical infrastructure such as electric power. RADICS will develop technologies to monitor heterogeneous distributed control system networks, detect anomalies that require rapid assessment, isolate compromised system elements, characterize attacks in real time, mitigate sensor spoofing and denial of service attacks, and restore services. Hardware-in-the-loop simulation techniques will be developed to enable the discovery of emergent vulnerabilities and the development and optimization of mitigation, restoration, and reconstitution strategies applicable to the power grid. This will include understanding the potential role of electric power markets and smart grid technologies in propagating or damping power grid anomalies. RADICS technologies will transition to military installations and commercial industry. ***FY 2015 Accomplishments:*** - Formulated resilient architectures for real-time monitoring, analysis, and assessment of distributed industrial control systems and physical infrastructure. - Investigated rapid re-provisioning techniques to quickly re-deploy firmware and operating system images to restore compromised devices back to a pristine, known state of operation. ***FY 2016 Plans:*** - Create a hardware-in-the-loop simulation capability to enable the discovery of emergent vulnerabilities and the development and optimization of mitigation strategies applicable to the U.S. power grid. - Develop technologies to monitor heterogeneous distributed industrial control system networks, detect anomalies that require rapid assessment, mitigate sensor spoofing and denial of service attacks, and restore services. - Extend simulation capabilities to understand the potential role of electric power markets in propagating or damping power grid anomalies. - Develop techniques that use organic sensors, remote instrumentation, and other sources of cyber situation awareness information to continuously optimize cyber defenses. ***FY 2017 Plans:*** - Validate emulations of embedded industrial control devices for development, test and evaluation of defensive cyber measures. - Explore techniques to enable validated dynamic simulations of cascading faults across large sections of a power grid. - Develop the means to produce a robust, multi-source time base with sufficient accuracy to enable continued operation of critical infrastructure in the event of a disruption of GPS signals. - Develop defense mechanisms for supervisory control and data acquisition systems that are subject to systematic/malicious attack in addition to random perturbations/failures.			
Title: High Assurance Cyber Military Systems	24.000	27.690	17.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
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 very 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. ***FY 2015 Accomplishments:*** - Formally verified full functional correctness for the extended core operating system and the automatically synthesized control systems for selected vehicles. - Demonstrated required security properties that follow from correctness for the extended core operating system and the automatically synthesized control systems. - Performed static and dynamic assessments after modifications were made on militarily-relevant vehicles to evaluate the effectiveness of the synthesis and formal methods tools. - Conducted a field test of a HACMS hardened operating system integrated in a helicopter mission computer during which live cyber attacks on unsecured applications were contained. ***FY 2016 Plans:*** - Apply an architecture-based approach to high-assurance system development to develop a large fraction of the software for a two-processor open-source quadcopter, a helicopter, an unmanned wheeled robot, and a military transport vehicle. - Demonstrate machine-tracked assurance cases for system-wide security properties on targeted vehicles. - Increase the level of automation of proof generation in theorem provers. - Evaluate the effectiveness of approaches by conducting penetration-testing exercises on the targeted vehicles. ***FY 2017 Plans:*** - Develop techniques for ensuring the predictable composability of adaptively assembled systems. - Formulate assurance cases for complex mission critical systems that are comprised of multiple interacting components. - Develop formal methods approaches to enable predictable system design at scale. - Evaluate the effectiveness of the formal methods approaches by conducting penetration-testing exercises.			
Title: Vetting Commodity Computing Systems for the DoD (VET)	21.987	22.625	18.019

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
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 attack. ***FY 2015 Accomplishments:*** - Improved the effectiveness of prototype tools, in particular by reducing the rates of false alarms and missed detections, through further competitive engagements. - Expanded the set of challenge programs to explore more complex forms of malicious hidden functionality including race conditions, information leakage, and defective encryption. - Replaced initial experimental platforms with more complex devices that are more operationally representative. ***FY 2016 Plans:*** - Measure 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. - Initiate development of an integrated vetting application that incorporates the most promising new techniques and scales to problems of operationally relevant size. - Conduct an integrated end-to-end software/firmware-vetting technology demonstration relevant to potential transition partners. ***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.			
Title: Cyber Grand Challenge (CGC) ***Description:*** The Cyber Grand Challenge (CGC) program will create 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, 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	6.233	11.329	11.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
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 2015 Accomplishments:*** - Created the robust competition infrastructure required to accommodate the large number of competitors. ***FY 2016 Plans:*** - Conduct world's first automated computer security contest: Cyber Grand Challenge Final Event. - Release event results as cyber research corpus to measure and challenge future automated cyber capabilities. ***FY 2017 Plans:*** - Use the lessons learned from the (first) Cyber Grand Challenge Final Event to design a follow-on competition in which competitor systems compete directly against experts. - Benchmark and baseline the abilities of expert reverse engineers to guide the creation of a machine-vs-expert competition corpus. - Initiate development of a competition infrastructure that allows for distributed machine-vs-expert tournament play.			
Title: Extreme Distributed Denial of Service Defense (XD3) ***Description:*** Building upon work in the Mission-oriented Resilient Clouds (MRC) program, the Extreme Distributed Denial of Service Defense (XD3) program will develop new computer networking architectures better able to 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 likely accelerate as the Internet of Things (IoT) expands to new classes of devices that in many cases will be deployed with inadequate security controls: attackers will incorporate poorly defended IoT devices in 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 Plans:*** - Formulate 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. - Develop network maneuver and deception techniques that increase adversary work factors in target development, attack planning, and execution.	-	14.996	26.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
- Devise 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 the attack while preserving performance for legitimate users. ***FY 2017 Plans:*** - Develop testing capabilities to support iterative experimentation and demonstration of prototypes. - Implement and integrate network dispersion, maneuver, and deception techniques in prototype systems that increase adversary work factors in target development, attack planning, and execution. - Perform system-level demonstrations and subject systems to critical assessments to pinpoint design weaknesses and vulnerabilities. - Conduct military field exercises in collaboration with transition partners to elicit feedback on XD3 features, capabilities, and concepts of operation.			
Title: Leveraging the Analog Domain for Security (LADS) ***Description:*** The Leveraging the Analog Domain for Security (LADS) program, building upon the Vetting Commodity Computing Systems for the DoD (VET) program, will develop and demonstrate 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 covert. ***FY 2016 Plans:*** - Formulate 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. - Investigate 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. - Propose 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).	-	10.000	19.000

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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 2015**	**FY 2016**	**FY 2017**
- Develop statistical models for side channel emissions given imprecise/probabilistic knowledge of the executed code.			
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 IT-03 for testing and evaluation through participation in tactical level exercises and integrating the Plan X system into transition partner operating profiles. ***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 Cyber Guard, Cyber Flag, and Red Flag. - Refine operator workflows and operational use cases based on exercise feedback. - Work with transition partners, such as U.S. Cyber Command (USCYBERCOM) and U.S. Army Cyber Command (ARCYBER), to integrate Plan X into current operating systems.	-	-	23.349
Title: System Security Integrated Through Hardware and software (SSITH) ***Description:*** System Security Integrated Through Hardware and software (SSITH) seeks to better protect DoD systems by exploring innovative approaches that combine hardware and software to provide enhanced system security. Traditional cybersecurity approaches have focused either on software or hardware, but rarely on an integration of both domains. By exploring integrated hardware/software solutions, SSITH will combine the efficiency and robustness of hardware with the flexibility and adaptability of software to provide security solutions that are resistant to attack and adaptive to new attack approaches. The program is based on the concept that co-design of hardware and software provides new modalities to protect electronic systems. The SSITH program will pursue several hardware/software approaches to enhancing electronic system security. First, the program will investigate new co-designed hardware/software architectures that are inherently more secure than current electronic systems. Second, the program will investigate hardware/software architectures that are flexible and can adapt to new system attack methods and vectors. Third, the program will examine methods to reduce the power/performance overhead required to implement novel and powerful protection methods recently conceived in the security community.	-	-	8.337

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
FY 2017 Plans: - Define new hardware/software architectures that implement flexible and robust protection against external attack. - Utilize modeling and simulation approaches to determine the expected improvement in protection of the new hardware/software architectures relative to software only and hardware only approaches.			
Title: Mission-oriented Resilient Clouds (MRC) ***Description:*** The Mission-oriented Resilient Clouds (MRC) program is creating 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 is addressing this risk by creating advanced network protocols and new approaches to computing in potentially compromised distributed environments. Particular attention is focused on adapting defenses and allocating resources dynamically in response to attacks and compromises. MRC will result in new approaches to measure trust, reach consensus in compromised environments, and allocate resources in response to current threats and computational requirements. MRC will develop new verification and control techniques for networks embedded in clouds that must function reliably in complex adversarial environments. ***FY 2015 Accomplishments:*** - Demonstrated automated construction of diverse, redundant network flow paths that maximize communication resilience in clouds. - Evaluated and measured the scalability and resilience of a high-assurance cloud computing application development library in terms of number of concurrent replicas supported and volume of data handled. - Developed and demonstrated hardened network services through fine-grained memory access controls that determine what valid memory addresses are read or written to by each instruction in a program. - Demonstrated concurrent optimization of computing resources and network bandwidth to achieve significant reduction in network load with no performance loss. - Inserted and evaluated multiple MRC technologies into U.S. Pacific Command (USPACOM) distributed computing environments. - Assessed technologies with Defense Information Systems Agency (DISA) to facilitate transitions into DoD networks and clouds. ***FY 2016 Plans:*** - Demonstrate correct, disruption-free upgrading of software defined networking controllers in live networks. - Complete transition of one or more technologies into operational use by USPACOM and DISA. - Transition secured version of multi-UAV control software to Air Force Research Laboratory (AFRL).	15.892	8.750	-
Title: Active Cyber Defense (ACD)	13.828	8.600	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
Description: The Active Cyber Defense (ACD) program will enable DoD cyber operators to fully leverage our 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 will exploit emerging 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 2015 Accomplishments:*** - Completed development of system components. - Performed a limited capability demonstration at CYBERFLAG 15-1 training exercise by successfully defending a targeted network enclave from attack. - Began integration of technologies into complete prototype platforms. - Tested integrated capabilities in collaboration with Director, Operational Test and Evaluation (DOT&E). ***FY 2016 Plans:*** - Complete integration of system platforms and demonstrate capabilities to transition partners. - Perform final test and evaluation of integrated capabilities and obtain approval for operational deployment. - Support initial operational fielding of capability to facilitate transition to DoD cyber operators.			
Title: Rapid Software Development using Binary Components (RAPID) ***Description:*** The Rapid Software Development using Binary Components (RAPID) program developed a system to identify and extract software components for reuse in new applications. The DoD has critical applications that must be ported to future operating systems. In many cases, the application source code is no longer available requiring these applications to continue to run on insecure and outdated operating systems, potentially impacting operations. Advanced technology development for the program was budgeted in PE 0603760E, Project CCC-04. ***FY 2015 Accomplishments:*** - Developed new software component reuse capabilities to extend application performance to a wider range of realistic scenarios and enable an expanded concept of operations. - Implemented new capabilities in modules designed to interoperate seamlessly with deployed RAPID prototype systems. - Integrated new modules into prototype RAPID systems deployed at transition partner sites and supported initial operations.	10.396	-	-
Title: Active Authentication	7.025	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
Description: The Active Authentication program developed more effective user identification and authentication technologies. Current authentication approaches are typically based on long, complex passwords and incorporate no mechanism to verify that the user originally authenticated is the user still in control of the session. The Active Authentication program addressed these issues by focusing on the unique aspects of the individual (i.e., the cognitive fingerprint) through the use of software-based biometrics that continuously validate the identity of the user. Active Authentication integrated multiple biometric modalities to create an authentication system that is accurate, robust, and transparent to the user. ***FY 2015 Accomplishments:*** - Demonstrated multiple authentication biometrics suitable for deployment on desktop and mobile hardware for potential use by the DoD. - Prototyped an authentication platform suitable for use on desktop and mobile hardware in collaboration with potential transition sponsors. - Proved flexibility of the underlying prototype platform by creating an additional authentication platform suitable for DoD.			
Title: Anomaly Detection at Multiple Scales (ADAMS) ***Description:*** The Anomaly Detection at Multiple Scales (ADAMS) program developed and applied algorithms for detecting anomalous, threat-related behavior of systems, individuals, and groups over hours, days, months, and years. ADAMS developed flexible, scalable, and highly interactive approaches to extracting actionable information from information system log files, sensors, and other instrumentation. ADAMS integrated these anomaly detection algorithms to produce adaptable systems for timely insider threat detection. ***FY 2015 Accomplishments:*** - Developed techniques for representing end-user knowledge and feedback to ensure that the machine learning algorithms are working with the most effective features possible. - Demonstrated and quantified performance of algorithms in a series of controlled tests on blended synthetic/real data. - Hardened prototypes and installed these in operational environments for testing and evaluation.	7.000	-	-
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 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 eliminate known vulnerabilities exploited by attackers. However, because novel attacks will be developed, CRASH also developed software techniques that allow a computer system	6.730	-	-

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
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 that make each computer system appear unique to the attacker and allow each system to change over time. ***FY 2015 Accomplishments:*** - Produced a hardened web server and browser that enable the creation of secure web applications from untrusted code. - Initiated two international standards submissions for securing web browsers and their communications. - Demonstrated policy-based application monitoring and hardware-assisted self-healing of multiple applications and hardware-based detection of malicious software. - Developed and demonstrated automated code randomization techniques to implement moving target defenses for software. - Developed and commercialized technology to detect hardware trojans in field programmable gate array (FPGA) components and provide host protection for embedded devices, including routers, printers and Voice over Internet Protocol (VoIP) phones.			
Title: Integrated Cyber Analysis System (ICAS) ***Description:*** The Integrated Cyber Analysis System (ICAS) program developed techniques to automatically discover probes, intrusions, and persistent attacks on enterprise networks. At present, discovering the actions of capable adversaries requires painstaking forensic analysis of numerous system logs by highly skilled security analysts and system administrators. ICAS technologies facilitate the correlation of interactions and behavior patterns across all system data sources and thereby rapidly uncover aberrant events and detect system compromise. This includes technologies for automatically representing, indexing, and reasoning over diverse, distributed, security-related data and system files. ***FY 2015 Accomplishments:*** - Developed and implemented algorithms for automatically identifying and quantifying specific security risks on enterprise networks. - Conducted initial technology demonstrations including automatic indexing of data sources, common language integration, and reasoning across federated databases. - Integrated, evaluated, and optimized algorithms via testing against attacks/persistent threats provided by transition partners. - Completed fully functional beta versions of the applications with operational stability suitable for testing at transition partner locations.	3.000	-	-
Accomplishments/Planned Programs Subtotals	170.959	202.252	255.137

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
IT-04: *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*	-	48.636	60.948	56.039	-	56.039	41.574	41.856	41.755	36.755	-	-

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; and to respond intelligently to new and unforeseen events. 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; and allow intelligence analysts to make sense of massive, incomplete, and contradictory information; and unmanned systems to operate safely with high degrees of autonomy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Low Resource Languages for Emergent Incidents (LORELEI)	17.875	22.225	28.620

Description: The Low Resource Languages for Emergent Incidents (LORELEI) program is developing the technology to rapidly field machine translation capabilities for low-resource foreign languages. The United States 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. Historically, exploiting foreign language materials required 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 will take 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 2015 Accomplishments:
- Explored techniques for optimizing combinations of existing resources to eliminate reliance on large parallel corpora.
- Proved viability of techniques to identify and link mentions of entities from text in a low-resource language to a knowledge base.
- Developed methodologies for generating morphological variants of a word and for clustering entity mentions.

FY 2016 Plans:
- Develop initial techniques for quantifying the linguistic similarity of language usage in diverse documents and media.
- Develop algorithms to exploit the universal properties of languages when rapidly ramping up for a low-resource language.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop semantic techniques for identifying the common topics, themes, and sentiment in speech and text in diverse foreign languages. - Collect, generate, and annotate data for an initial set of resources in typologically representative medium-resource languages. - Create 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 two new languages and measure progress on the languages evaluated in the previous year. - Work with end users to utilize and evaluate the interface platform.			
Title: Deep Exploration and Filtering of Text (DEFT) ***Description:*** The Deep Exploration and Filtering of Text (DEFT) program is developing language technology to enable automated extraction, processing, and inference of information from text in operationally relevant application domains. A key DEFT emphasis is to determine explicit and implicit meaning in text through probabilistic inference, anomaly detection, and other techniques. To accomplish this, DEFT will develop and apply formal representations for basic facts, spatial, temporal, and associative relationships, causal and process knowledge, textually entailed information, and derived relationships and correlated actions/ events. DEFT inputs may be in English or in a foreign language and sources may be reports, messages, or other documents. DEFT will extract knowledge at scale for open source intelligence and threat analysis. Planned transition partners include the intelligence community and operational commands. ***FY 2015 Accomplishments:*** - Developed technology for extracting belief, sentiment and intent, for representing geo-spatial features and temporal events, and for inference from a set of documents. - Integrated multiple complementary algorithms into a comprehensive and consistent functional suite to support end-user workflows and problems. - Focused algorithm development on knowledge base representation in preparation for embedding algorithms in workflows to enable reasoning and downstream analysis. - Initiated work to adapt algorithms to specific foreign languages. - Conducted performance evaluations on event representation and other aspects of knowledge base population.	23.933	30.223	17.419

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Transitioned multiple algorithms and conducted effectiveness assessments at multiple end-user sites. ***FY 2016 Plans:*** - Improve algorithm performance on current functions and expand to new functions such as extending currently single-document algorithms to function across multiple documents. - Improve the discovery of different ways in which names of people and other entities are expressed across multiple documents, and develop techniques for linking them together. - Merge and optimize combined output of algorithms focused on different tasks such as belief and sentiment extraction, event argument and attribute identification, and relation mapping. - Develop methods for evaluating the effectiveness of various natural language processing algorithms in a multi-lingual environment, including evaluation of sentiment and belief analysis. - Transition an initial system-level prototype and additional component prototypes to end-user sites for effectiveness assessment. - Refine areas of focus based on results of transition site evaluations and open evaluation performance. ***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.			
Title: Robust Automatic Transcription of Speech (RATS) ***Description:*** The Robust Automatic Transcription of Speech (RATS) program is developing 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 of interest include speech activity detection, language identification, speaker identification, and keyword spotting. RATS technology is being developed and optimized on real world data in conjunction with several operational users. ***FY 2015 Accomplishments:*** - Developed new methods for field adaptations, which include lightly supervised and unsupervised adaptation of the algorithms to new channels and environments. - Developed methods for coping with extraneous signals found in field data. - Developed techniques to reduce the data required to adapt algorithms to new channels from hours to minutes.	6.828	8.500	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Produced a software integrated platform with a set of Application Programming Interfaces (APIs) and Graphical User Interfaces (GUIs) to be inserted at DoD and intelligence community partner sites and tested in the working environment of the partners. ***FY 2016 Plans:*** - Develop, integrate and test techniques to deal with multiple speakers and overlapping speaker channels. - Collect and annotate additional field collected data. - Develop unified API and interface to support multiple tactical integration platforms. - Integrate technologies in transition partner platforms, adjusting systems to fit partner needs. - Evaluate technologies on specialized operational scenarios.			
Title: Understanding Machine Intelligence (UMI) ***Description:*** The Understanding Machine Intelligence (UMI) program will develop techniques that enable artificial intelligence (AI) systems to better support users through transparent operation. If current trends continue, future U.S. military autonomous systems will need to perform increasingly complex and sensitive missions. AI will be critical to such autonomous systems, but in order for developers, users, and senior leaders to feel confident enough to deploy and use AI-enabled systems, they must operate with high degrees of transparency, reliability, predictability, and safety. UMI will develop AI technologies that support transparency by providing supporting rationale and logic sequences that establish the basis for and reliability of outputs. In addition, efforts will be made to develop a mathematically rigorous virtual stability theory for AI-enabled systems analogous to the (conventional) stability theory developed for dynamical systems (solutions to systems of differential equations). Such a virtual stability theory will enable the creation of feedback mechanisms that flag, interrupt, and modify anomalous outputs and behaviors to ensure safe, predictable operation. UMI implementations will be developed and demonstrated in next-generation decision-support and autonomous systems. This program was previously funded in PE 0602702E, Project TT-13. ***FY 2017 Plans:*** - Formulate approaches for AI systems to explain their behavior and clarify the basis for and reliability of outputs. - Develop automated drill-down techniques that provide users with logic/data that drives AI system outputs/behaviors. - Develop a mathematically rigorous virtual stability theory for AI-enabled logic systems analogous to the (conventional) stability theory developed for dynamical systems. - Propose a general technology for building systems with the ability to understand, explain, and modify their behavior.	-	-	10.000
Accomplishments/Planned Programs Subtotals	48.636	60.948	56.039

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *LANGUAGE UNDERSTANDING AND SYMBIOTIC AUTOMATION*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
IT-05: *CYBER TECHNOLOGY*	-	63.891	39.664	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Cyber Technology project develops 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 will ensure 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 2015	FY 2016	FY 2017
Title: Plan X	38.161	29.800	-

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 2015 Accomplishments:
- Created runtime environment and platforms capable of supporting a large scale user base, massive-scale deployments, resiliency to failure of any system component, and managed high ingest rates.
- Demonstrated military network tactical situational awareness applications and use cases.
- Released Plan X 1.0 system and field tested capabilities at Cyber Guard 2015.
- Conducted field tests of computer network operations scenario development and training capabilities.
- Planned transition to operational environments including understanding of transition partner networks and integration points.

FY 2016 Plans:
- Publish application store software development kit and integrate third party cyber capabilities.
- Refine analytics features for battlespace, analysis of courses of action, and planning subsystems.
- Adopt and integrate security access and use privileges, and demonstrate large-scale deployment of the end-to-end system with users in disparate locations.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Integrate with existing military command and control/intel systems to allow bidirectional flow of data to and from Plan X to provide visualization and insights into the cyber battlespace. - Release Plan X 2.0 system and field test capabilities at Cyber Flag 2016, and initiate technology transition with USCYBERCOM and Service components.			
Title: Cyber Grand Challenge (CGC) ***Description:*** The Cyber Grand Challenge (CGC) 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, 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 2015 Accomplishments:*** - Conducted mid-term qualification of finalist automated cyber technologies through competitive challenge. - Began second phase development of automated cyber defenders to allow real time in situ network defense decision-making. - Released first of two cyber research measurement and experimentation corpora with associated competition results. ***FY 2016 Plans:*** - Conduct world's first automated computer security contest: CGC Final Event. - Prepare automated systems for final competition via a multi-month series of audited trials. - Release final event results as cyber research corpus to measure and challenge future automated cyber capabilities.	16.832	9.864	-
Title: Crowd Sourced Formal Verification (CSFV) ***Description:*** The Crowd-Sourced Formal Verification (CSFV) program created technologies that enable crowd-sourced approaches to securing software systems through formal verification. Formal software verification is a rigorous method for proving that software has specified properties, but formal verification does not currently scale to the size of software found in modern weapon systems. CSFV enabled non-specialists to participate productively in the formal verification process by transforming formal verification problems into user-driven simulations that are intuitively understandable. ***FY 2015 Accomplishments:*** - Completed development of five new simulations. - Refined simulations to make them accessible to a large set of non-specialists.	8.898	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Augmented simulations to handle large Java and C computer programs consisting of hundreds of thousands of lines of source code. - Enhanced public website to include these new simulations. - Assessed effectiveness of the new simulations on large-sized code targets.			
Accomplishments/Planned Programs Subtotals	63.891	39.664	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

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Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	42.447	24.265	21.250	-	21.250	11.014	13.469	14.346	14.346	-	-
BW-01: *BIOLOGICAL WARFARE DEFENSE*	-	42.447	24.265	21.250	-	21.250	11.014	13.469	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 include 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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	43.780	29.265	18.250	-	18.250
Current President's Budget	42.447	24.265	21.250	-	21.250
Total Adjustments	-1.333	-5.000	3.000	-	3.000
• Congressional General Reductions	0.000	-5.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	-1.333	0.000			
• TotalOtherAdjustments	-	-	3.000	-	3.000

Change Summary Explanation

FY 2015: Decrease reflects the SBIR/STTR transfer.
FY 2016: Decrease reflects congressional reduction.
FY 2017: Increase reflects program repricing in Defense Against Mass Terror Threats.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
Title: Medical Countermeasures	18.447	9.750	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 2015 Accomplishments:*** - Demonstrated an expanded set of IVTCs able to reproduce the function of four human physiological systems. - Demonstrated an automated prototype system for monitoring the health and response of IVTCs to test compounds. - Designed and built additional modules that are compatible with the expanded set of IVTCs and enable the platform to sustain the integrated IVTCs for two weeks. - Demonstrated that the expanded set of four IVTCs individually respond and react 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 four 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 2016 Plans:*** - Demonstrate an expanded set of IVTCs able to reproduce the function of seven 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 three weeks. - Demonstrate that the expanded set of seven IVTCs individually respond and react to test compounds in a manner consistent with the known effects of those compounds on the corresponding human tissues. - Demonstrate 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.			
Title: Defense Against Mass Terror Threats	24.000	14.515	14.168

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602383E I *BIOLOGICAL WARFARE DEFENSE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
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 2015 Accomplishments:*** - Developed the requirements for a low cost, pervasive detection network for wide-area monitoring of radionuclide exposure. - Demonstrated novel manufacturing approaches that can lower the cost of radiation detectors without compromising performance. ***FY 2016 Plans:*** - Develop high performance radiation detectors for wide-area monitoring and implement novel manufacturing approaches for low cost production. - Develop and study 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.			
Accomplishments/Planned Programs Subtotals	42.447	24.265	21.250

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

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

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Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	299.787	302.582	313.843	-	313.843	381.964	370.283	403.688	407.797	-	-
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	61.648	52.128	43.024	-	43.024	53.544	64.765	43.451	53.451	-	-
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	57.521	63.118	52.847	-	52.847	62.527	68.518	96.298	101.298	-	-
TT-06: *ADVANCED TACTICAL TECHNOLOGY*	-	14.861	13.468	6.500	-	6.500	0.000	0.000	0.000	0.000	-	-
TT-07: *AERONAUTICS TECHNOLOGY*	-	50.245	31.621	62.876	-	62.876	95.361	62.424	51.434	42.434	-	-
TT-13: *NETWORK CENTRIC ENABLING TECHNOLOGY*	-	115.512	142.247	148.596	-	148.596	170.532	174.576	212.505	210.614	-	-

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: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E I *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 Network Centric Enabling Technology project develops network-centric mission applications that integrate 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 streams in tactically-relevant timeframes. The data processing efforts include: 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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	299.734	314.582	386.540	-	386.540
Current President's Budget	299.787	302.582	313.843	-	313.843
Total Adjustments	0.053	-12.000	-72.697	-	-72.697
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	-12.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	9.182	0.000			
• SBIR/STTR Transfer	-9.129	0.000			
• TotalOtherAdjustments	-	-	-72.697	-	-72.697

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2015	FY 2016
Project: TT-03: *NAVAL WARFARE TECHNOLOGY*		
Congressional Add: *Arctic Operations Congressional Add*	4.250	-
Congressional Add Subtotals for Project: TT-03	4.250	-
Congressional Add Totals for all Projects	4.250	-

Change Summary Explanation

FY 2015: Increase reflects reprogrammings offset by the SBIR/STTR transfer.

FY 2016: Decrease reflects congressional reduction.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E I *TACTICAL TECHNOLOGY*

FY 2017: Decrease reflects completion of the Ground Experimental Vehicle program, the transition of the Endurance program to Budget Activity 3, and drawdown of the XDATA and Network Defense programs.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	61.648	52.128	43.024	-	43.024	53.544	64.765	43.451	53.451	-	-

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 2015	FY 2016	FY 2017
Title: Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV)	27.100	6.000	4.000

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 2015 Accomplishments:
- Integrated software and hardware into the ACTUV platform.
- Initiated development of alternative payloads.

FY 2016 Plans:
- Complete construction of prototype vessel.
- Initiate at-sea testing to validate baseline performance of vessel, sensor systems, and autonomy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Move the vessel from the contractor facility to a Navy facility in San Diego for long term testing - with the Office of Naval Research (ONR). - Demonstrate improved situational awareness and autonomy capabilities, incorporating advanced above water sensors. - Demonstrate the ability to successfully integrate new mission payloads, including a Mine Counter Measures (MCM) payload. ***FY 2017 Plans:*** - 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 Upward Falling Payloads (UFP) program will develop forward-deployed unmanned distributed systems that can provide non-lethal effects or situational awareness over large maritime environments. Building upon and complimenting concepts for maritime situational awareness and 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 can be commanded from standoff to launch to the surface. Advances in miniaturized sensors and processors, growth in the variety of unmanned systems, and advances in autonomy and networking all point toward highly capable, yet affordable, distributed systems. However, power and logistics to deliver these systems in a timely manner in forward operating areas limit their utility. The UFP program will remove this barrier to accelerate large-scale unmanned distributed missions. The presumption is that a wider range of technology options and system solutions will emerge when the barriers to deployment are removed. ***FY 2015 Accomplishments:*** - Developed UFP nodes scalable in size, to enable extended survival at full depth. - Demonstrated launch of a UFP surrogate payload from land and method for aerodynamically stable deployment of an unmanned aerial vehicle (UAV) from a UFP node. - Initiated design of payload subsystems for sensing, communicating, and locating. - Developed signaling scheme and performed sea test for long range underwater acoustic communications for triggering. - Demonstrated integration of triggered release from surrogate underwater cabled system. - Studied alternative communication modalities. - Demonstrated surfacing of UFP balloon-node riser and deployment of small UAV. ***FY 2016 Plans:*** - Demonstrate deep-ocean surfacing of scalable riser prototype to the surface and launch of payload surrogate from UFP node at surface.	18.955	15.901	14.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
- Demonstrate launch of a UFP surrogate payload after being submerged for several months. - Demonstrate long-range acoustic communications sufficient to wake up a UFP node. - Demonstrate launch of UAV from UFP node at surface. ***FY 2017 Plans:*** - Develop communications and ISR payloads for UFP nodes. - Demonstrate complete launch of UAV from ocean depth. - Integrate parafoil kite with submerged tow body. - Integrate and demonstrate remote triggering of dormant UFP node. - Conduct major integrated sea test at full depth.			
Title: Strategic Mobility ***Description:*** The goal of the Strategic Mobility program is to analyze and perform risk reduction on technology solutions which can enable rapid deployment of brigade- or even division- sized forces globally in a matter of just days. Initially, the activity will focus on identifying high payoff logistics and deployment technologies, and understanding the deployment and sustainment architectures required to support these technologies. The program will examine increased automation in logistics and distribution operations, new platform technologies for sea-based transportation and prepositioning, and technologies which could enable aerial delivery of forces to the vicinity of an objective area. The Strategic Mobility program will then shift to a focused technology risk reduction activity designed to systematically address the principal risks for the highest payoff technology set. The technologies developed by the program could enable a rapid strategic response capability, with rapid deployment and sustainment of substantial ground combat forces, even to very remote or austere locations. ***FY 2016 Plans:*** - Create time and cost model of brigade level deployment technologies and processes. - Perform refined technology trade studies to identify critical component technology to aid in extremely rapid loading, unloading, and unpacking of transports and filling of requisitions to include building boxes/pallets and loading of materials into containers. - Initiate studies into foundation and structure required to enable reliable operation of robotic logistics systems in expeditionary environments. ***FY 2017 Plans:*** - Complete technology trade studies to identify critical component technologies to aid in extremely rapid loading and unloading of transports, unpacking of supplies from transports, and filling requisitions. - Complete studies in foundation and structure required to enable reliable operation of robotic logistics systems in expeditionary environments.	-	2.727	2.000
Title: Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES)	11.343	27.500	23.024

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
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 2015 Accomplishments:*** - Initiated technology development efforts focusing on guidance, packaging and delivery method. - Began detailed subsystem design and plans for later stage risk reduction tests and prototyping. - Began end-to-end modeling and simulation of all candidate designs to determine Point of Departure (POD) designs. - Began examining candidate platforms for out-year live-fire tests. - Completed government in-house feasibility and trade study. - Conducted projectile wind tunnel testing to verify performance predictions. ***FY 2016 Plans:*** - Determine Point of Departure (POD) designs. - Complete end-to-end modeling and simulation of POD designs. - Begin risk reduction tests and prototyping. - Update models and simulations as designs are modified. - Conduct risk reduction subsystem tests to verify gun hardening and performance. - Perform unguided projectile flight tests to validate aerodynamic models and gun-launch survivability. - Coordinate with Navy for integrated tests to include approved representative targets. ***FY 2017 Plans:*** - Update models and simulations of select designs. - Complete preliminary prototype design. - Perform initial controlled projectile flight tests to assess projectile performance. - Conduct fire control tests for target acquisition and tracking and interceptor projectile tracking.			
Accomplishments/Planned Programs Subtotals	57.398	52.128	43.024

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-03 / *NAVAL WARFARE TECHNOLOGY*

	FY 2015	FY 2016
Congressional Add: Arctic Operations Congressional Add ***FY 2015 Accomplishments:*** - Conduct additional study work on technologies to assure U.S. capability to achieve situational awareness in the Arctic.	4.250	-
Congressional Adds Subtotals	4.250	-

C. Other Program Funding Summary ($ in Millions)

Line Item	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
• ACTUV: *Office of Naval Research MOA*	2.000	7.000	9.000	-	9.000	4.000	0.000	0.000	0.000	-	-

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	57.521	63.118	52.847	-	52.847	62.527	68.518	96.298	101.298	-	-

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 2015	FY 2016	FY 2017
Title: Ground Experimental Vehicle (GXV) ***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 2015 Accomplishments:*** - Initiated GXV technology development efforts. - Began developing parametric models for evaluating military utility of technologies. ***FY 2016 Plans:*** - Continue GXV technology development efforts focused on increasing mobility, survivability through agility and crew augmentation. - Mature parametric models for evaluating military utility of technologies. - Complete studies focusing on system trades relating to system power requirements, size/caliber of weapon systems, and crew size.	22.601	24.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
- Complete studies focusing on the impact of crew augmentation capabilities on the size and cognitive workload of combat vehicle crews. - Conduct survivability analysis of individual concepts.			
Title: Squad X	25.500	31.118	36.847
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 a new Hybrid Squad unit. ***FY 2015 Accomplishments:*** - Initiated technology development efforts, focusing on squad precision effects, non-kinetic engagement, enhanced sensor fusion and exploitation, and squad collaborative autonomy. - Completed initial integration and architecture trade studies. - Initiated squad architecture, technology evaluation, and experimentation studies. - Initiated development of virtual, constructive, and live experimentation plan; defined modeling and simulation strategy. - Initiated development of virtual test bed. - Conducted Tactical Edge Standards Boards (TESBs) and service-level operational workshops. ***FY 2016 Plans:*** - Complete systems architecture, technology evaluation, and experimentation trade studies. - Conduct Squad X Baseline experimentation, through virtual and live experiments to obtain a system performance baseline. - Refine technology development efforts focusing on squad precision effects, non-kinetic engagement, enhanced sensor fusion and exploitation, and squad collaborative autonomy. - Implement modeling and simulation environment to allow for an overarching iterative design process and obtain system performance estimation. - Leverage Squad X testbed and simulation environments to iteratively assess developed technology and architecture schemes. - Demonstrate initial individual technology capabilities in technology assessments.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Conduct 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. - Complete Squad X Baseline experimentation. - Initiate planning for system-level experimentation and evaluation in relevant conditions with operational units. - Demonstrate individual technology capabilities for squad precision effects, non-kinetic engagement, enhanced sensor fusion and exploitation, and squad collaborative autonomy in operational environment. - Initiate technology development efforts focusing on human machine interfaces and the squad common operating picture. - Initiate squad-system development efforts focusing on the development of automatic systems to increase squad performance and the integration of previously developed technologies and enhancing for dismounted operations. - Conduct Tactical Edge Standards Boards.			
Title: Counter Unmanned Air Systems (C-UAS) and Force Protection (CFP) ***Description:*** The Counter Unmanned Air Systems (C-UAS) and Force Protection (CFP) program will examine advanced detection, tracking, and system defeat capabilities to counter emerging threats posed against U.S. military forces. Key research will include an analysis of system threat phenomenologies where non-state and state actors seek to leverage asymmetries by employing small unmanned systems and other threats to include rocket propelled grenades, anti-tank munitions, and indirect fires. The program will consider technologies supporting U.S. ground, air, and maritime operations. Central research and development will factor in analysis of advanced sensor integration, detection, and weapons engagement capabilities within operationally relevant environments (urban, tactical, and strategic domains). ***FY 2017 Plans:*** - Perform trade studies for a systems approach. - Conduct operational analysis and technology maturity assessments to determine the minimum set of critical system attributes and technology advances required for C-UAS and CFP.	-	-	9.000
Title: Mobile Infantry ***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	-	6.000	7.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
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 Plans:*** - Complete trades of mission/vignette-driven collaborative command and control of a MI unit composed of a warfighter team and semi-autonomous systems. - Complete trade studies and initial estimates of perception and autonomous algorithms required to match vignettes. - Complete 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.			
Title: Robotics Fast Track ***Description:*** To be dominant in robotics of the future, the DoD will need to embrace programs designed to create disruptive advances in robotics capabilities that are measured in months rather than years, and whose individual costs may largely be measured in thousands of dollars rather than millions. The Robotics Fast Track program seeks to revolutionize robotics technologies by promoting non-traditional technical opportunities. The program will create low-cost, high-utility robotic component solutions that result in prototype systems and proofs of concept in months. The Robotics Fast Track program will engage numerous robotics related efforts across the spectrum of robotics professionals and enthusiasts, extending the existing performer base. The program will demonstrate the ability for robotics projects to be performed at an asymmetric advantage in time, cost, and contribution of the efforts. ***FY 2015 Accomplishments:*** - Began execution of multiple performance developments. ***FY 2016 Plans:*** - Continue execution of multiple performance developments. - Release initial robotics fast track catalog.	4.500	2.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Host transition workshops to facilitate follow-on developments with other U.S. government entities.			
Title: Robotics Challenge ***Description:*** The Robotics Challenge program sought to boost innovation in autonomous systems and expand platform utility through enhanced actuation, energy density, perception, locomotion, agile reconfiguration, and design efficiency. Program thrusts were centered on a progressive regimen of physical problem solving, real-time team oriented tasks, and dynamic adaptation designed to build "machine trust", especially when integrated with humans in a variety of operational environments. The Robotics Challenge program consisted of a series of obstacle course style challenge events that focused on technology solutions to demonstrate and test robot capabilities for disaster response. The program drove advances in power systems, agility and speed, precision in perception tied to platform coordination, dexterity, and impulsive power. Program objectives focused on technologies to expand mobility and extend endurance of unmanned platforms, advanced tactile and manipulation capabilities, and tools for cost effective design, validation, and construction of autonomous technology, and human-robot interaction. The 6.3 portion of this program was budgeted in PE 0603766E, Project NET-01. ***FY 2015 Accomplishments:*** - Conducted the DARPA Robotics Challenge Finals. - Performed analysis and reported findings to document advancements achieved as a result of the challenge.	4.920	-	-
Accomplishments/Planned Programs Subtotals	57.521	63.118	52.847

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
TT-06: *ADVANCED TACTICAL TECHNOLOGY*	-	14.861	13.468	6.500	-	6.500	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 2015	FY 2016	FY 2017
Title: Laser Ultraviolet Sources for Tactical Efficient Raman (LUSTER)	4.500	7.000	6.500
Description: The Laser Ultraviolet Sources for Tactical Efficient Raman (LUSTER) program is developing a compact semiconductor laser that emits in the deep UV (i.e., wavelength < 250 nanometers (nm)) and is capable of an output power of 1 Watt (W) with high efficiency and spectral purity suitable for a wide array of spectroscopy applications. Such an achievement will represent a significant advance over the state of the art, as existing lasers in this wavelength range are bulky, highly inefficient, and expensive, as there are no available semiconductor lasers that can emit in the UV range < 250 nm. LUSTER will leverage lessons learned in growing high quality light emitting material from the Compact Mid-Ultraviolet Technology (CMUVT) program. The compact size of semiconductor lasers along with the LUSTER performance goals will enable many applications including but not limited to standoff Raman spectroscopy which is of interest for DoD applications such as chemical agent sensing. ***FY 2015 Accomplishments:*** - Demonstrated low loss thulium doped tellurite fibers for use in amplification of blue emission. - Demonstrated high quality quantum well material that exhibited optically pumped UV emission in the 220-240 nm range. - Initiated the design and growth of laser epitaxial material, focusing on low-defect growth, optimal electrical and optical confinement, and methods for high efficiency and power operation. - Evaluated methods for using non-linear crystals to efficiently convert longer wavelength lasers in the 500 nm range down to the 250 nm range and identified Beta Barium Borate (BBO) as best performing non-linear optical crystal. ***FY 2016 Plans:*** - Optimize laser epitaxial material, electron-beam source, and frequency multiplying nonlinear crystals for higher efficiency and high power operation. - Develop compact low power electronics for driving and controlling photonic and mechanical components. - Demonstrate working prototype of a deep UV laser system that meets the Phase 1 metrics of > 100 mW output power, 0.4% total system efficiency and line width less than 0.1 nm. ***FY 2017 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Demonstrate a deep UV laser system that meets 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 ***Description:*** The Endurance program will develop technology for pod- or internally-mounted lasers to protect airborne platforms from emerging and legacy electro-optical/infrared (EO/IR) guided surface-to-air missiles. The Endurance system will be a completely self-contained laser weapon system brassboard in an open architecture configuration. The focus will be on miniaturizing component technologies, developing high-precision target tracking, identification, and lightweight agile beam control to support target engagement. The program will also focus on determining the laser irradiance and dwell time required to defeat both emerging and legacy missile threats. The advanced technology component of this program is budgeted in PE 0603739E, Project MT-15. ***FY 2015 Accomplishments:*** - Spectrally combined the output of four kW-class, near perfect beam quality fiber lasers in a packaged compact, rugged spectral beam combiner. - Achieved the objective high-speed slew and settle rates for the beam director (BD) with an inertial surrogate of the preliminary BD design. - Developed a concept for robust high-precision tracking of threat missiles throughout the engagement. - Initiated 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.). ***FY 2016 Plans:*** - Conduct effects testing on an available surrogate of the seeker of a larger class of threat EO/IR guided surface-to-air missile to verify estimated lethality criteria and anchor lethality models. - Complete 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.). - Conduct key risk reduction experiments to support the design of robust, high-precision tracking. - Demonstrate robust, high-precision tracking against multiple low-speed surrogate targets at representative angular line-of-sight rates and ranges. - Partially-package high-power laser for pod-integration testing. - Fabricate and test smallest high-power beam director and control system yet demonstrated.	7.161	6.468	-
Title: International Space Station SPHERES Integrated Research Experiments (InSPIRE) ***Description:*** The International Space Station SPHERES Integrated Research Experiments (InSPIRE) program utilized the DARPA-sponsored Synchronized Position, Hold, Engage, and Reorient Experimental Satellites (SPHERES) platform, which has	3.200	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
flown onboard the International Space Station (ISS) since May 2006, to perform a series of multi-body formation flight experiments that necessitate a medium-duration zero-gravity environment. InSPIRE enhanced the ability to rapidly mature and insert new technologies into national security space assets. The InSPIRE program expanded on the capabilities matured through SPHERES by developing, building, and launching new hardware and software elements that expand the baseline capabilities. These capabilities will enable use of SPHERES as a testbed for more complex experimentation, providing affordable opportunities to test new space technologies. ***FY 2015 Accomplishments:*** - Launched the new docking ports for SPHERES to enhance rendezvous and docking test capabilities. - Conducted on-orbit testing of new SPHERES docking ports. - Developed and executed additional rendezvous and proximity operations experiments using SPHERES inside ISS.			
Accomplishments/Planned Programs Subtotals	14.861	13.468	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: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
TT-07: *AERONAUTICS TECHNOLOGY*	-	50.245	31.621	62.876	-	62.876	95.361	62.424	51.434	42.434	-	-

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 2015	FY 2016	FY 2017
Title: Aircrew Labor In-cockpit Automation System (ALIAS)	20.284	14.621	19.876
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 2015 Accomplishments:*** - Designed and commenced prototyping of an initial ground-based ALIAS system. - Initiated simulator-based demonstration of complete automation system including training and adaptation of system to multiple crew member roles. - Conducted ground and airborne risk reduction testing and demonstrations. ***FY 2016 Plans:*** - Perform ground demonstration of ALIAS system mission functionality. - Conduct flight demonstration of contingency management and new command interface. - Demonstrate portability to new aircraft type. - Continue risk reduction activities. ***FY 2017 Plans:*** - Conduct flight demonstration of perception and actuation subsystems.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Perform ground demonstration of portability timeline into other aircraft. - Initiate airworthiness evaluation for integrated flight demonstration. - Initiate the transition of select knowledge acquisition, perception, and interface technologies to operational aircraft.			
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 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 2015 Accomplishments:*** - Initiated new studies of novel technologies. ***FY 2016 Plans:*** - Perform modeling of concepts and architectures. - Conduct trade studies of emerging concepts. ***FY 2017 Plans:*** - Perform testing of enabling technology components. - Initiate conceptual system designs.	2.000	2.000	2.000
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 Plans:*** - Conduct exploratory trade studies to establish feasibility of technical approaches. - Initiate studies on integration with existing Service systems and systems architectures.	-	15.000	36.000

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Conduct system concept design tradeoff analyses. ***FY 2017 Plans:*** - Initiate engineering of integrated demonstration concepts. - Conduct system and subsystem risk reduction test planning. - Develop objective system concepts and mission capability projections. - Complete Preliminary Design Review for demonstration system.			
Title: Swarm Challenge ***Description:*** The goal of the Swarm Challenge is to develop autonomous swarming algorithms for Unmanned Vehicles (UxVs) to augment ground troops performing missions in a complex environment, without creating a significant cognitive burden. The program will evaluate the effectiveness of swarming for UxVs supporting ground operations, air operations, maritime operations, undersea operations, or search and rescue operations. Challenges include the ability for the UxV to collaborate to rapidly survey an area leveraging other UxVs to solve problems related to, for example, perception, decision making, or obstacle clearing. The challenge emphasizes minimum operator training and supervision so that the operator can continue to perform his/her normal duties while using UxVs as force multipliers. ***FY 2015 Accomplishments:*** - Performed trade studies for system approach. - Select architecture for software, communication, computation, perception, and simulation environment. - Develop autonomous algorithms and associated software.	3.000	-	-
Title: 21st Century Propellants ***Description:*** The 21st Century Propellants program will examine new classes of solid propellants capable of affording solid fueled rockets the ability to perform in a greater range of operating scenarios. The program will provide current and future missile systems the flexibility in speed-range combinations unachievable in current solid propellants and will reduce current volume and weight forms for smaller rocket systems. Successful propellant systems for this program must demonstrate a controlled burn rate, restart capability, termination control, improved safety, and a dramatically improved shelf life (>15 years). The program will also address critical issues of safer manufacturing (improved operational handling, transportability issues, and improved environmental impact). Advanced manufacturing methods are of special interest because they can assure reproducibility and can support building custom propellant grains for different rocket systems. ***FY 2017 Plans:*** - Initiate new studies of novel technologies. - Conduct risk reduction tests of candidate technologies.	-	-	5.000
Title: Vertical Take-Off and Landing (VTOL) Technology Demonstrator	21.961	-	-

Exhibit R-2A, **RDT&E Project Justification:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
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% 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% of the gross weight with a payload capacity of at least 12.5% 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. In FY 2016, VTOL Technology Demonstrator will be funded in PE 0603286E, Project AIR-01. ***FY 2015 Accomplishments:*** - Initiated preliminary design of configuration and all subsystems. - Held system definition reviews to evaluate subsystem integration into air vehicle design and technology development paths to meet program objectives. - Performed subscale wind tunnel and laboratory testing for aerodynamic data base and flight controls development. - Refined power generation and distribution/integration concepts. - Performed propulsion and power system scaled model bench testing. - Designed and developed subscale flight models for configuration viability and control law validation. - Fabricated and began ground testing of subscale model in preparation for flight testing in FY 2016. - Validated computational performance predictions against empirical data. - Refined full scale engine integration design. - Created detailed system integration plans. - Prepared detailed airworthiness and flight test preparation requirements in support of the subscale flight test schedule.			
Title: Petrel ***Description:*** The Petrel program investigated advanced capabilities for the rapid transport of large quantities of cargo and equipment, such as during the deployment of a heavy brigade combat team, from CONUS to the battlefield, reducing the deployment timeline for mechanized land forces and critical supplies anywhere in the world to under seven days at a price point comparable or slightly in excess of conventional sealift. ***FY 2015 Accomplishments:*** - Investigated component technologies with potential to enable specific concepts, including advanced propulsion and materials. - Explored innovative approaches for significantly increasing lift to drag ratio.	3.000	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Evaluated approaches to rapidly deliver cargo and equipment directly from offshore to the battlefield without infrastructure.			
Accomplishments/Planned Programs Subtotals	50.245	31.621	62.876

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
TT-13: *NETWORK CENTRIC ENABLING TECHNOLOGY*	-	115.512	142.247	148.596	-	148.596	170.532	174.576	212.505	210.614	-	-

A. Mission Description and Budget Item Justification

The Network Centric Enabling Technology project develops applications that integrate 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. The data processing efforts include: 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 2015	FY 2016	FY 2017
Title: XDATA	31.217	32.917	13.896
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 supporting 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 2015 Accomplishments:*** - Developed methods for interactive, iterative, and distributed analysis of diverse data at petabyte scale. - Optimized analytic methods and software for implementation on heterogeneous platforms and operating environments. - Optimized visualization technology to rapidly adapt to new missions and contexts. - Demonstrated the initial implementation of a rich library of software tools for rapid use in mission and user specific contexts. - Demonstrated end-to-end systems on data and problems of users from DoD, intelligence, and law enforcement communities. ***FY 2016 Plans:*** - Develop methods and software for interactive, iterative, distributed analysis of diverse data enabling transition, integration and implementation on heterogeneous platforms.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop new analytic methods for distributed data and systems through the development of enhanced machine learning and algorithmically scalable methods. - Develop a scalable, robust framework for user-defined, adaptable visualizations. - Develop, test and benchmark a library of user interfaces which provide a consistent user experience independent of scale or processor heterogeneity. - Demonstrate that applications deployed from a library of interfaces reduce design to testing time and increase reusability of components across multiple mission systems and user-defined requirements. ***FY 2017 Plans:*** - Develop integrated applications from components and interface libraries demonstrating flexible adaptation to emergent user requirements and ad-hoc tasking. - 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.			
Title: Network Defense ***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 and to detect recurring threats, patterns of activity, and persistent vulnerabilities. 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 2015 Accomplishments:*** - Enhanced network analytics to detect structured attacks across multiple networks. - Created general purpose algorithms for detecting novel classes of attacks across multiple networks. - Developed methods for identifying persistent vulnerabilities within a network and across multiple networks. - Evaluated and optimized techniques on realistic network data. ***FY 2016 Plans:*** - Develop algorithms that use scanning events to provide indications and warning of coordinated adversary activities. - Enhance persistent vulnerability detection techniques and work with potential users to identify vulnerabilities particular to individual organizations/networks and/or shared by multiple organizations/networks.	27.500	31.002	16.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Demonstrate the capability to use summary information about an attack on one network to automatically detect similar attacks on other networks. ***FY 2017 Plans:*** - Optimize algorithms that detect anomalous behaviors and coordinated adversary activities through exercises using summary data and on-site evaluations. - Demonstrate the capability to anticipate specific attack formats on one network based on attacks observed on other similar networks. - 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.			
Title: Memex ***Description:*** The Memex program is developing the next generation of 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 and the iterative search process they enable is time-consuming and inefficient, typically finding 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 2015 Accomplishments:*** - Developed initial domain-specific search engines to automatically discover, access, retrieve/extract, parse, process, analyze, and manage web content in specified domains. - Implemented the base capabilities to index the surface, deep, and dark web and non-traditional structured and unstructured content that is dynamically-generated, unlinked, and in unconventional formats. - Developed information extraction techniques to categorize and classify discovered content based on mission/user task requirements. - Developed dynamic, interactive, and collaborative user interface capabilities to support the needs of specialized users.	22.338	29.300	27.700

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Developed search techniques optimized for queries performed for anti-human-trafficking investigations and provided these to law enforcement to support case development and criminal prosecution. ***FY 2016 Plans:*** - Develop specialized search techniques for information discovery in networks of illicit activity. - Develop advanced content discovery, deep crawling, information extraction, and information relevance algorithms to support domain specific search. - Integrate and evaluate multiple end-to-end operational prototypes with automated, user, and team guided methods for web content analysis. - Conduct system evaluation with feedback from operational partners and transition mature capabilities for use in operational settings. ***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. - 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. - Establish and develop software and user communities around open source components and applications to ensure tool sustainment, software evolution, and long-term operational use.			
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 2015 Accomplishments:*** - Developed detailed system architecture for the distributed battle management system.	11.024	14.440	18.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Developed workflow and Concepts of Operations (CONOPS) for the human operator to interact with the battle management system. - Developed and prototyped the protocols and algorithms for distributed battle management in a denied environment. - Stood-up modeling and simulation capability for test and performance evaluation and began testing of prototype architecture and algorithms. ***FY 2016 Plans:*** - Identify and further research the most promising planning concepts, situation understanding concepts, and systems integrator. - Complete design of the overall DBM system, to include architecture, software components, CONOPS, and integration strategy for expected host platforms. - Implement initial version of the integrated DBM system architecture, algorithms, and software. - Demonstrate 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. - Conduct software flexibility tests to demonstrate the ability to insert software upgrades without disrupting the BM structure.			
Title: Quantitative Crisis Response (QCR)* ***Description:*** *Previously Quantitative Methods for Rapid Response (QMRR) The Quantitative Crisis Response (QCR) program develops and applies big data analysis and visualization methodologies to better understand the true nature of non-traditional threats, track the effectiveness of remedial measures, and develop/optimize alternative strategies. Recently we have seen the rise of extremely challenging non-traditional threats including illicit networks of (human) traffickers and infectious diseases like Ebola. To counter illicit networks it is important to detect their activities, which often take place on the dark web, and derive their command and control structure. Infectious disease contagion presents a somewhat different challenge, specifically, finding patterns in the spread of the disease and factors that favor/mitigate its propagation. There is also interest in quantitative methods for countering the proliferation of weapons of mass terrorism. QCR will be coordinated with and transitioned to multiple national security agencies. ***FY 2015 Accomplishments:*** - Developed quantitative models to track the impact of Ebola on a population, with emphasis on social and economic factors.	7.600	15.588	21.500

Exhibit R-2A, **RDT&E Project Justification:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Developed advanced content discovery, deep crawling, information extraction, and information relevance algorithms to support search, analysis and visualization of collected information. - Coordinated with stakeholders in national security agencies and developed mechanisms for transitioning technology to operations. ***FY 2016 Plans:*** - Refine quantitative models, content discovery, deep crawling, information extraction, and information relevance algorithms to support search, analysis and visualization of collected information. - Generalize mechanisms and harden collection and processing architectures to respond to rapid re-direction of system resources and apply developed models, processes and methods to other areas of national security interest. - Develop dynamic, interactive, and collaborative user interface capabilities to support the needs of users. - Develop quantitative models to discover indicators of possible proliferation of weapons of mass terrorism. ***FY 2017 Plans:*** - Integrate collection architectures, analytic models, processes and methods into operational prototypes. - Evaluate multiple end-to-end operational prototypes with automated, user, and team guided methods for web content analysis and visualization. - Conduct system evaluation with feedback from operational partners and transition mature capabilities for use in operational settings. - Develop algorithms for extracting trace signals from large data sets to enable tracking potential proliferation of weapons of mass terrorism.			
Title: Media Forensics (MediFor) ***Description:*** The Media Forensics (MediFor) program will create technologies for analyzing diverse types of content and media to determine their trustworthiness for military and intelligence purposes. Current approaches to media forensics are manpower intensive and require analysts and investigators to undertake painstaking analyses to establish context and provenance. MediFor 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. This program was previously funded in PE 0603767E, Project SEN-03. ***FY 2015 Accomplishments:*** - Formulated approaches for automatically detecting when image and video files have been altered or manipulated. - Collected images and videos and manually manipulated a subset for training and evaluation of the technology.	9.729	14.000	18.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Initiated development of techniques for detecting inconsistent observations. ***FY 2016 Plans:*** - Develop advanced techniques for media fingerprinting and the ability to search large repositories for content produced by the same device. - Define 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. - Develop cross media representations of semantic content in image and video sources and techniques to indicate where the sources reinforce or contradict each other. - Collect and manipulate additional images and videos for evaluation and training of algorithms. ***FY 2017 Plans:*** - Develop approaches for countering evolving media editing technologies. - Develop approaches to detect manipulation in noisy, degraded and highly compressed media. - Develop means to fuse knowledge from the various technology components and inference engines to determine the relation between manipulation and the intended application. - Develop an integrated platform with Graphical User Interfaces (GUIs) for operator communication.			
Title: Science of Human and Computer Teaming ***Description:*** The Science of Human and Computer Teaming program will develop and demonstrate data-driven approaches for the formation and training of teams comprised of humans and computers. Conventional approaches to military personnel selection, role assignment, and training are optimized for individual performance, but military operations are typically performed by teams, and future teams are likely to also include autonomous systems that use artificial intelligence (AI) to sense, reason, learn, and interact. Behavioral scientists are studying the performance of groups across diverse sets of tasks and developing performance assessment techniques for group work. Interesting early results suggest that groups exhibit a form of intelligence beyond that of the individual members, and that group intelligence has social correlates. Computer scientists are looking at ways in which humans may team with computers to achieve superior levels of performance. Such human-computer teams have shown great promise in highly structured competitive domains such as chess. Realizing this promise in free-form (battlefield) environments will require intuitive, low-latency, high-bandwidth, human-computer interfaces that enable computers to be better teammates. The program will identify individual characteristics predictive of performance of mixed human-computer teams; develop techniques for measuring these characteristics in military personnel; demonstrate the capability to select, assign roles, and train human-computer teams with performance superior to that of human-only teams formed and trained using current methods; and develop an understanding of how to structure human-computer teams for superior performance on military missions such as cyber defense and intelligence analysis.	-	-	15.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
FY 2017 Plans: - Develop group psychometrics concepts applicable to human-computer teams. - Identify individual characteristics that are readily measured and are predictive of individual performance in human-computer teams assigned specific military task types. - Develop quantitative approaches for creating high-performing human-computer teams through the inclusion of individuals and computers/autonomous systems with complementary characteristics. - Develop human-computer-interface design principles that optimize the contribution made by computer-based teammates to human-computer team performance. - Formulate human-machine teaming strategies for military missions such as cyber defense and intelligence analysis.			
Title: Predicting Complex Operational Environments ***Description:*** The Predicting Complex Operational Environments program expands on prior work in the XDATA program and will develop advanced modeling, analysis, simulation, and visualization tools to enable command staffs to rapidly and effectively plan and manage missions in complex 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. Economic disruptions can add great urgency to these considerations, as shortages of water and food directly impact theater security and may even lead to war. Current mission planning and plan assessment/adaptation technologies do not adequately model the inherent uncertainties. Addressing this challenge will require the creation of new semantic techniques that automatically generate, update, and prune alternative hypotheses as they become more or less likely given incoming data streams. The program will create computational models that represent the most significant dynamics and uncertainties of the operational environment including political, military, economic, and social factors. These will enable command staffs to develop and assess potential courses of action at multiple levels of granularity and time scales, and to quickly adapt to changing situations in complex operational environments. ***FY 2016 Plans:*** - Formulate computational models for political, military, economic, and social factors in complex operational environments to support military planning and plan assessment/adaptation at multiple levels of granularity and time scales. - Create semantic techniques that automatically generate, update, and prune alternative hypotheses as they become more or less likely given incoming data streams. ***FY 2017 Plans:*** - Develop dynamical systems models for projecting and predicting the interactions between diverse stakeholder groups that may have differing priorities, sensitivities and concerns.	-	5.000	18.000

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop displays for rapidly visualizing and evaluating likely outcomes of alternative U.S. courses of action. - Implement models for operational environments and run initial simulations that would be required to support military planning and plan assessment/adaptation. - Introduce models that capture the impact of natural and human-mediated perturbations, such as water shortages, crop failures, and hoarding of critical resources, on theater security. - Develop machine-reading and automated model assembly techniques to enable prediction of the theater security ramifications of natural resource shortages and economic disruptions.			
Title: Visual Media Reasoning (VMR) ***Description:*** The Visual Media Reasoning (VMR) program created technologies to automate the analysis of enemy-recorded photos and videos and to identify, within minutes, key information related to the content. This included identification of individuals within the image (who), enumeration of the objects within the image and their attributes (what), and determining the image's geospatial location and time frame (where and when). Large data stores of enemy photos and video are available but cannot be easily leveraged by a warfighter or analyst attempting to understand a specific new image in a timely fashion. The VMR program developed technology to enable users to gain insights rapidly through application of highly parallelized image analysis techniques that can process the imagery in massive distributed image stores. VMR technology serves as a force-multiplier by rapidly and automatically extracting tactically relevant information and alerting the analyst to scenes that warrant the analyst's expert attention. ***FY 2015 Accomplishments:*** - Included mechanisms for technical users to add new computer vision algorithms to the system. - Provided a quantified level of performance to show the advantage of multi-algorithm reasoning versus a single-algorithm approach. - Delivered robust full-featured Version 1.0 to National Media Exploitation Center (NMEC), FBI, AFRL, and other Government agencies as transition products.	6.104	-	-
Accomplishments/Planned Programs Subtotals	115.512	142.247	148.596

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *NETWORK CENTRIC ENABLING TECHNOLOGY*

E. Performance Metrics

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

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Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602715E *I MATERIALS AND BIOLOGICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	144.409	206.115	220.456	-	220.456	233.910	254.357	262.098	266.659	-	-
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	90.101	124.172	121.703	-	121.703	110.492	118.560	121.928	125.928	-	-
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	54.308	81.943	98.753	-	98.753	123.418	135.797	140.170	140.731	-	-

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, materials processing techniques, mathematical models and fabrication strategies for advanced materials, 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 materials including structural materials and devices, functional materials and devices, energetic materials and devices, low distortion optical lenses, and materials that enable new propulsion concepts for land, sea, and space vehicles.

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 in the application of biomimetic materials and devices for Defense, the use of biology's unique fabrication capabilities to produce structures that cannot be made any other way, the application of materials in biological applications, and the development of manufacturing tools that use biological components and processes for materials synthesis. This project also includes major efforts aimed at integrating biological and digital sensing methodologies and maintaining human combat performance despite the extraordinary stressors of combat. Finally, this thrust will develop new cognitive therapeutics, investigate the role of complexity in biological systems, and explore neuroscience technologies.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	150.389	220.115	263.319	-	263.319
Current President's Budget	144.409	206.115	220.456	-	220.456
Total Adjustments	-5.980	-14.000	-42.863	-	-42.863
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	-14.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-1.400	0.000			
• SBIR/STTR Transfer	-4.580	0.000			
• TotalOtherAdjustments	-	-	-42.863	-	-42.863

Change Summary Explanation

FY 2015: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2016: Decrease reflects congressional reduction.
FY 2017: Decrease reflects a reduction to Materials Processing and Manufacturing efforts and completion of the Manufacturable Gradient Index Optics (M-GRIN) program.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	90.101	124.172	121.703	-	121.703	110.492	118.560	121.928	125.928	-	-

A. Mission Description and Budget Item Justification

The major goal of the Materials Processing Technology project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced materials, 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 materials including structural materials and devices, functional materials and devices, energetic materials and devices, low distortion optical lenses, and materials that enable new propulsion concepts for land, sea, and space vehicles.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Materials Processing and Manufacturing	18.479	20.387	15.234
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 systems. It will also develop approaches that yield new materials and materials capabilities 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 (3D printing, manufacture on demand, etc.) 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. Further research within this thrust, will create methods to translate natural inputs into software code and mechanical design. This process will complete underspecified designs when possible and initiate an iterative dialog with a human to specify details as needed and actively suggest changes to designers when the intended design cannot operate within the required specifications. ***FY 2015 Accomplishments:*** - Demonstrated integrated, physics-based, location-specific computational tools that predict the thermal history, residual stress, residual distortion, and microstructure of In718 alloys produced by direct metal laser sintering (DMLS). - Implemented in-process quality assurance (IPQA) sensors and technology capable of capturing DMLS processing data and initiated development of optimized capture of real-time data at appropriate resolutions to forecast article quality. - Demonstrated initial operational phenomenological metallurgical models that link electron beam direct manufacturing (EBDM) process parameters to microstructure and material properties for location-specific prediction of ultimate tensile strength throughout a built structure. - Demonstrated automated X-Y-Z wire position control system based on real-time, fast rate, solid-state backscattered electron sensor system. - Simulated high-fidelity probabilistic process window (including tails) for bonded composite structures using Monte Carlo techniques and a priori knowledge of process variables.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Completed verified 2D and 3D bonded composite pi-joint structure models. - Established interoperable process-material model assessment framework, and curated and standardized a data management system to capture and store data from materials and manufacturing research. ***FY 2016 Plans:*** - Complete design of experiments-optimized model for the probabilistic process model. - Demonstrate predictive capability of the probabilistic process model. - Complete optimized phenomenological yield strength model for electron beam additive manufacturing (EBAM). - Complete neural network and genetic numerical analysis for EBAM process. ***FY 2017 Plans:*** - Complete verification and validation of probabilistic processing model suite. - Validate phenomenological model framework. - Demonstrate rapid qualification capability on demonstration components.			
Title: Multifunctional Materials and Structures ***Description:*** The Multifunctional Materials and Structures thrust is developing materials, materials processing, and structures that are explicitly tailored for multiple functions and/or unique mechanical properties. One goal of this research is the ability to design, develop, and demonstrate materials with combinations of properties that are normally orthogonal (e.g., damage tolerance and biocompatibility). This capability will ultimately lead to enhanced lethality, survivability, and performance in future DoD platforms. This thrust will also include the exploration and development of dynamic models of complex systems across scale and develop new methodologies for understanding, architecting, and engineering complex systems. These computational tools will link material properties to physics across multiple length scales (from molecule to part) and provide the ability to model and exploit complexity, such as hierarchy and strongly correlated effects, in structural and functional materials. Development efforts under this thrust include reactive structures that can serve as both structure and explosive for lightweight munitions, novel materials and surfaces that are designed to adapt structural or functional properties to environmental and/or tactical threat conditions, and new thin film material deposition processes to improve the performance of surface dominated properties (friction, wear, and membrane permeability). In addition, this thrust will also explore new cost effective processes for ensuring DoD accessibility to future advanced materials. Examples of DoD applications that will benefit from these material developments include lower weight and higher performance aircraft, turbines with enhanced efficiency, erosion-resistant rotor blades, and high-temperature materials for operation in hypersonic environments. ***FY 2015 Accomplishments:*** - Experimentally validated computational models of low temperature thin-film growth. - Integrated in situ thin film characterization techniques for real-time qualitative and quantitative analysis of growth processes.	18.748	28.085	24.158

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Demonstrated deposition of thin film challenge material on a substrate at low temperature. - Improved film quality and properties by adjusting process component parameters/integration strategy. - Generated design intent and the initial materials solution for a baseline hypersonic flight trajectory. - Established and populated the data warehouse for initial boost-glide aeroshell data. - Developed an initial framework for modeling complex systems made from tailorable feedstock materials and forming processes applicable to many domains. ***FY 2016 Plans:*** - Deliver thin film and coating materials with technical summaries to transition partners, Army Research Office and the Naval Research Laboratory. - Demonstrate initial integrated material, process, design, and manufacturing tool demonstrations for hypersonic hot structure aeroshell. - Create material system development and design framework, and link material informatics results to identify aeroshell mission performance drivers. - Generate a sub-component design concept and a sub-element design for hypersonic hot structure aeroshell. - Establish an independent test and evaluation capability for hypersonic hot structure aeroshell. - Identify candidate reinforced matrix compounds for enabling multiple platforms to be manufactured from a single tailorable feedstock material. - Identify reconfigurable forming technologies for the rapid, cost effective manufacture of complex shapes from matrix compounds reinforced with short, aligned elements. ***FY 2017 Plans:*** - Demonstrate an aligned and tailorable material feedstock that meets or exceeds state of the art aerospace materials performance. - Demonstrate a reconfigurable forming method that maintains alignment and distribution in short element reinforced matrix compounds when formed into complex shapes for DoD parts. - Demonstrate that a multifunctional element can be incorporated into the feed stock and maintain performance. - Demonstrate that a multifunctional component can be formed without degradation of performance in either the structural or functional component. - Create a cost model that assesses cost competitiveness and rate insensitivity of the new material format and forming process. - Establish process limits of forming capabilities.			
Title: Materials for Force Protection ***Description:*** The Materials for Force Protection thrust is developing novel materials and materials systems that will greatly enhance performance against ballistic, blast, and chemical threats across the full spectrum of warfighter environments. Included	16.223	25.353	27.361

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
in this thrust are energy management and armor approaches to address explosively formed projectiles and shaped charges as well as new novel approaches for containment and remediation of chemical agent threats. The thrust will also focus on novel topological concepts as well as entirely new structural designs and chemistries that will afford enhanced, sustainable protection, and functionality at reduced weight and/or cost. ***FY 2015 Accomplishments:*** - Demonstrated at least 30% enhancement in opaque vehicle ballistic armor performance for combined bullet-frag threats over state-of-the-art fielded designs. - Demonstrated capability, based on small arms threat results, to achieve at least 30% enhancement in opaque vehicle ballistic armor performance to defeat bullets from heavier weapons. - Developed capability, based on results of feasibility study, to achieve 2x enhancement in opaque vehicle ballistic armor performance for multiple threats in an integrated armor design. - Developed and demonstrated ability of monohull design to spread impulsive load from enhanced (> 2x impulsive load) underbody blast and prevent breach at equivalent weight to current underbody structures. - Integrated energy absorbing materials and components into passive hierarchical energy absorbing systems characteristic of various vehicle weight classes and demonstrated capability to reduce by > 2x the combined effects of local and global impulse in underbody blast events. - Demonstrated capability to reduce by > 2x the combined effects of local and global impulse in active counter impulse systems characteristic of medium vehicle weights in underbody blast events. - Demonstrated capability to reduce by > 4x the effects of both local and global impulse by combining hierarchical passive energy absorbing systems into an integrated system characteristic of light and medium vehicle weight class in underbody blast events. - Explored novel approaches to chemical remediation of organic compounds with a focus on approaches that utilize readily available reagents (e.g., soil, water, and air). - Developed modeling capability for predicting material properties relationships such as density, strength, and toughness in hierarchical structures. - Initiated the development of knowledge-based tools to enable computational design and discovery of complex synthetic chemistry reaction pathways. - Initiated the design of a user interface for exploiting computational synthetic chemistry to predict complex reaction pathways. ***FY 2016 Plans:*** - Validate chemical remediation approaches against a series of DoD-relevant model compounds. - Demonstrate feasibility for achieving an efficiency of chemical agent remediation/conversion of > 99%. - Expand computational methods for reaction pathway design of structurally simple active pharmaceutical ingredients (APIs) such as ibuprofen and atropine.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Demonstrate 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 synthesis of one challenge molecule in a fully automated system.			
Title: Functional Materials and Devices ***Description:*** The Functional Materials and Devices thrust is developing advanced materials and components that can improve the performance of a wide variety of functional devices for DoD sensing, imaging, and communication applications. One focus area under this thrust is the development of improved transductional materials that convert one form of energy to another (i.e., thermal to electrical, magnetic to electrical, etc.). Improvements in transductional materials and devices require deliberate control of material structure at the scale of the relevant phenomena. This thrust leverages advances in multi-physics modeling to identify and predict optimal material and device designs for a broad range of DoD applications. Examples of DoD applications that will benefit from advanced transductional materials include low size, weight and power (SWaP) thermoelectric coolers for DoD infrared sensors and compact RF antennas. ***FY 2015 Accomplishments:*** - Began the identification of DoD application-specific system specifications that will provide performance requirements for thermoelectric material development efforts. - Initiated study of novel power electronic circuit topologies to take advantage of emerging multiferroic materials for reduced size and weight. ***FY 2016 Plans:*** - Initiate the development of an open source model architecture and platform applicable for multiple transductional material domains (e.g. thermoelectric, magnetoelectric, multiferroic). - Continue the identification of DoD application-specific system specifications that will provide performance requirements for thermoelectric material development efforts. - Begin development of a multi-physics transductional material modeling capability that incorporates interface modeling and phonon engineering. - Design, fabricate and characterize thermoelectric materials and devices with improved performance metrics over the state-of-the-art.	6.000	13.734	14.680

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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 2015	FY 2016	FY 2017
- Design, fabricate and characterize materials and devices based on multiferroic or phase change materials with improved performance metrics over the state-of-the-art. ***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.			
Title: Reconfigurable Structures ***Description:*** In the Reconfigurable Structures thrust, new combinations of advanced materials, devices, structural architectures, and platforms are being developed to allow military systems to adapt to changing mission requirements and unpredictable environments. This includes the demonstration of new materials and devices that will enable the military to function more effectively in the urban theater of operations. In addition, this thrust will develop a principled, scientific basis for improved robotic mobility, manipulation, and supervised autonomy; and, leverage these results to develop and demonstrate innovative robot design tools, fabrication methods, and control methodologies. One specific objective of this thrust is to create the scientific basis for understanding, modeling, developing, testing and evaluating autonomous systems with one or more human supervisors, and one or more remote physical agents. Another thrust is the development of architectures that harness systems and human organizations working collaboratively. ***FY 2015 Accomplishments:*** - Investigated new control algorithms to enable sensing and processing for fast autonomous maneuvers in cluttered environments. - Designed platforms for low-Size, Weight and Power (SWaP) experimentation involving fast autonomous maneuvers. ***FY 2016 Plans:*** - Determine limits for GPS free navigation for short duration missions. - Model and develop behavioral controls to enable an Intelligence Surveillance and Reconnaissance (ISR) mission in a moderate-clutter environment. - Exploit novel mathematical tools and techniques for understanding the fundamentals of design science and design phenomena in complex systems and systems-of-systems. - Investigate architectures that harness systems and human organizations working together. ***FY 2017 Plans:*** - Develop representations and behaviors that enable an ISR mission in a high-clutter environment.	11.337	17.694	23.310

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Establish new paradigms for how systems and their constituent modules are represented, manipulated, integrated, and optimized. - Demonstrate management of complexity to enable inverse design of systems and capabilities.			
Title: Compact Neutron Sources ***Description:*** The Compact Neutron Sources thrust will develop the platform technologies for revolutionary portable energetic sources for in-field sensing, detection, and imaging. A focus of this thrust will be the development of compact neutron sources. Today's neutron imaging technology allows for unique sensing modalities that can currently only be performed at facility-sized installations. The research and development pursued under this thrust will enable the use of neutron imaging and detection in the field at time-scales and logistical footprints compatible with DoD missions. Multiple component technologies, such as new multi-functional materials with tuned physical and electrical characteristics and high-efficiency ion sources, will be developed and integrated in laboratory demonstration test beds. ***FY 2015 Accomplishments:*** - Developed and refined notional high-voltage particle accelerator system architectures for neutron production. - Designed components with 10-100x performance in key metrics as determined by system architecture requirements. - Developed and used high-performance design tools to conduct design and feasibility studies on accelerator and plasma components. ***FY 2016 Plans:*** - Incorporate technical findings from component design into expected performance metrics for integrated accelerators. - Refine components and begin integration into demonstration neutron source testbed. - Use component performance tests for design tool validation and development. ***FY 2017 Plans:*** - Identify successful compact neutron source components and integrate them into prototype systems. - Perform initial integrated compact neutron source prototype testing.	11.500	15.854	16.960
Title: Manufacturable Gradient Index Optics (M-GRIN) ***Description:*** The Manufacturable Gradient Index Optics (M-GRIN) program seeks 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 will expand 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 creates 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 seeks to extend GRIN manufacturing	7.814	3.065	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
technologies to glass, ceramic, and other inorganic materials in order 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 is to develop new design tools that enable optics designers to incorporate dynamic material properties, fabrication methods, and manufacturing tolerances. The integration of new materials, design tools, and manufacturing processes will enable previously unattainable 3-D optical designs to be manufactured. This new manufacturing paradigm will enable flexible production of GRIN optics in quantities of one unit to thousands of units. ***FY 2015 Accomplishments:*** - Completed GRIN lens production scale-up and demonstrated process control as measured against target yield and cost to enable sustainable manufacturing. - Upgraded design tools and expanded potential user pool from advanced to mid-level optical designers, through upgrades and improvements of the GRIN design modules, to provide user-friendly interface for customers. - Completed expansion of design tools to add 3D and arbitrary gradients as well as improve computational efficiency. - Completed process characterization and control to achieve target yields and turn-around times. - Initiated prototype builds to demonstrate system performance and/or size, weight and power (SWaP) improvement from GRIN optical systems. - Initiated thermal model and implement in optical system design to mitigate thermal effect on optical performance. - Initiated demonstration of rapid redevelopment/prototyping capability. ***FY 2016 Plans:*** - Complete prototype builds to demonstrate system performance and/or SWaP improvement from GRIN optical systems. - Complete thermal model and implement in optical system design to mitigate thermal effect on optical performance. - Complete demonstration of rapid redevelopment/prototyping capability.			
Accomplishments/Planned Programs Subtotals	90.101	124.172	121.703

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	54.308	81.943	98.753	-	98.753	123.418	135.797	140.170	140.731	-	-

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. 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 2015**	**FY 2016**	**FY 2017**
Title: BioDesign	13.916	13.500	13.582
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 2015 Accomplishments: - Utilized high throughput approaches to characterize intracellular components and mechanistic interactions that reveal the effects of challenge compounds on intracellular machinery. - Demonstrated high throughput methods using cells of human origin. - Demonstrated the ability to identify intracellular components and events that occur hours after the application of a challenge compound. - Demonstrated the ability to localize relevant molecules and events to one intracellular compartment (membrane, nucleus, or cytoplasm) upon the application of a challenge compound.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	Project (Number/Name) MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Reconstructed and confirmed greater than 20 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 2016 Plans:*** - 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. - Demonstrate the ability to identify intracellular components and events that occur within minutes after the application of a challenge compound. - Reconstruct and confirm 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. - 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.			
Title: Living Foundries ***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,	24.838	28.900	27.700

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
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 2015 Accomplishments:*** - Expanded the capabilities of the rapid design and prototyping infrastructure to target molecules that are difficult or costly to produce using traditional synthesis mechanisms. - Expanded access and experimental scale to promote the production capabilities of rapid design and prototyping facilities infrastructure. - Began establishing the efficacy of the integrated design-build-test-learn feedback cycle for forward design and rapid optimization of target molecules via the prototyping facility's established processes. ***FY 2016 Plans:*** - Demonstrate the ability of infrastructure pipelines to rapidly generate target molecules. - Initiate 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. - Implement learn capabilities into design algorithms based on testing and characterization of previously prototyped targets in order to improve the processes. - Improve forward design and rapid optimization of target molecules via the prototyping facility's established processes. - Initiate 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 known, but currently biologically inaccessible, molecules.			
Title: Adaptive Immunomodulation-Based Therapeutics ***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	12.554	22.000	22.971

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	Project (Number/Name) MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
map the bioelectric code modulates. 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. ***FY 2015 Accomplishments:*** - Initiated development of capabilities to characterize the neural-immune interface, including real-time measurement of biomarkers. - Began identifying novel, actionable targets for neural immune modulation. - Started identifying specific neuro-visceral circuits which can be targeted by electrical, optical, ultrasonic, or other novel stimulation approaches to modulate function. ***FY 2016 Plans:*** - Develop novel interface technologies to monitor and stimulate peripheral nerves to selectively alter organ function. - Compare specificity of novel interface technologies with state of the art whole-nerve stimulation devices. - Define input/output models of mammalian autonomic functions such as the immune system and/or the autonomic stress response. - Identify peripheral intervention points and modulation parameters for control of mammalian autonomic function for improving health or treating disease. - Develop 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.			
Title: Biological-Computational Platforms ***Description:*** The Biological-Computational Platforms program is a multi-disciplinary effort that combines neuroscience, biology, advanced computer science, mathematical modeling, and novel interfaces to create hybrid biological-computational platforms	-	8.468	10.382

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
for DoD applications. The program will research and develop tools that enable improved integration of biological processes and computing systems for facilitating perception, communication, and control. Novel hardware and software developed through this program will be able to operate on relevant environmental, physiological and neural information. The ultimate goal of this work is to develop hybrid biological-computational interfaces that optimize human-computer effectiveness. ***FY 2016 Plans:*** - Analyze architectures and systems for utilizing complex biological signals generalizable across users. - Investigate new approaches for neural sensor design to provide high spatial and temporal resolution without the use of an invasive microelectrode implant. - Begin studying approaches to transform neural representations of meaning, content and intentionality to new communications protocols with devices and computers. ***FY 2017 Plans:*** - Integrate multimodal input processing and demonstrate successful capacity for real-time feedback signaling to enable task performance. - Facilitate neurophysiologic-computer interfaces that enable direct control of multiple aspects of fixed facilities and mobile platforms. - Identify and quantify parameters of normal task performance involving fixed and mobile platforms. - Develop methods for assembling and rapidly deploying suites of physiologic and environmental sensors for integration with machine learning.			
Title: Biological Robustness in Complex Settings (BRICS) ***Description:*** The Biological Robustness in Complex Settings (BRICS) program will leverage newly developed technologies to enable radical new approaches for engineering biology. 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 genetic engineering of 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. This program has basic research efforts funded in PE 0601101E, Project TRS-01. ***FY 2016 Plans:*** - Develop technologies to design and build biological pathways that will function in undomesticated microbial species from a wide range of phyla (prokaryotic or eukaryotic).	-	9.075	10.200

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	Project (Number/Name) MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop 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. - Fabricate generalizable culture substrates that provide control over community structure and composition and support the growth of both prokaryotic and eukaryotic cells. ***FY 2017 Plans:*** - Integrate 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 complex laboratory environments. - Demonstrate potential for safe use of engineered consortia under conditions relevant to specific applications.			
Title: Enhancing Neuroplasticity ***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 functions with the Department of Defense, including foreign language learning, or data and intelligence analysis. ***FY 2017 Plans:*** - Determine the effects of nerve stimulation parameters (amplitude, rate, and timing) on brain regions that modulate plasticity. - Compare effectiveness of deep and superficial nerve stimulation sites in promoting synaptic plasticity and improving performance on language learning tasks. - Demonstrate effects of training on tuning functions of neurons in auditory and speech areas of the brain. - Perform studies to compare neurophysiology and learning effects of invasive and noninvasive stimulators.	-	-	13.918
Title: Neuroscience Technologies ***Description:*** The Neuroscience Technologies thrust leveraged recent advances in neurophysiology, neuro-imaging, cognitive science, molecular biology, and modeling of complex systems to sustain and protect the cognitive functioning of the warfighter faced with challenging operational conditions. Warfighters experience a wide variety of operational stressors, both mental and physical, that degrade critical cognitive functions such as memory, learning, and decision making. These stressors also degrade the warfighter's ability to multitask, leading to decreased ability to respond quickly and effectively. Currently, the long-term impact of these stressors on the brain is unknown, both at the molecular and behavioral level. This thrust area investigated modern neuroscientific techniques to develop quantitative models of this impact and explored mechanisms to protect, maintain, complement, or restore physical and cognitive functioning during and after exposure to operational stressors. In addition, new	3.000	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
approaches for using physiological and neural signals to make human-machine systems more time efficient and less workload intense were identified. ***FY 2015 Accomplishments:*** - Investigated methods to exploit recent advances in neurophysiology recording technologies, cognitive science, and engineering in conjunction with emerging solutions in neurally enabled human-machine interface technologies to characterize dynamics of human cognitive functions such as memory, learning, and decision making. - Exploited recent advances in computational analysis, systems identification, data intensive computing, and statistical inference methods to research novel computational tools for rapid analysis, validation, and integration of computational models of the brain. - Researched methods for joint computation and operations between biological systems and traditional digital computing systems.			
Accomplishments/Planned Programs Subtotals	54.308	81.943	98.753

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

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Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	169.690	174.798	221.911	-	221.911	234.424	236.582	233.270	245.370	-	-
ELT-01: *ELECTRONICS TECHNOLOGY*	-	169.690	174.798	221.911	-	221.911	234.424	236.582	233.270	245.370	-	-

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.

Advances in microelectronic device technologies, including digital, analog, photonic and MicroElectroMechanical Systems (MEMS) devices, continue to have significant impact in support of defense technologies for improved weapons effectiveness, improved intelligence capabilities and enhanced information superiority. The Electronics Technology program element supports the continued advancement of these technologies through the development of performance driven advanced capabilities, exceeding that available through commercial sources, in electronic, optoelectronic and MEMS devices, semiconductor device design and fabrication techniques, and new materials and material structures for device applications. A particular focus for this work is the exploitation of chip-scale heterogeneous integration technologies that permit the optimization of device and integrated module performance.

The phenomenal progress in current electronics and computer chips will face the fundamental limits of silicon technology in the early 21st century, a barrier that must be overcome in order for progress to continue. The program element will therefore explore alternatives to silicon-based electronics in the areas of new electronic devices. The program element will also explore new architectures to use devices of all types, new software to program the systems, and new methods to fabricate the chips. Approaches include nanotechnology, nanoelectronics, molecular electronics, spin-based electronics, quantum-computing, new circuit architectures optimizing these new devices, and new computer and electronic systems architectures. Projects will investigate the feasibility, design, and development of powerful information technology devices and systems using approaches for electronic device designs that extend beyond traditional Complementary Metal Oxide Semiconductor (CMOS) scaling, including non-silicon-based materials technologies to achieve low cost, reliable, fast and secure computing, communication, and storage systems. This investigation is aimed at developing new capabilities from promising directions in the design of information processing components using both inorganic and organic substrates, designs of components and systems leveraging quantum effects and chaos, and innovative approaches to computing designs incorporating these components for such applications as low cost seamless pervasive computing, ultra-fast computing, and sensing and actuation devices.

This project has five major thrusts: Electronics, Photonics, MicroElectroMechanical Systems, Architectures, Algorithms, and other Electronic Technology research.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*

B. Program Change Summary ($ in Millions)

	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	169.203	174.798	170.783	-	170.783
Current President's Budget	169.690	174.798	221.911	-	221.911
Total Adjustments	0.487	0.000	51.128	-	51.128
• 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	5.640	0.000			
• SBIR/STTR Transfer	-5.153	0.000			
• TotalOtherAdjustments	-	-	51.128	-	51.128

Change Summary Explanation

FY 2015: Increase reflects reprogrammings offset by the SBIR/STTR transfer.

FY 2016: N/A

FY 2017: Increase reflects initiation of new start programs: Limits of Thermal Sensors (LOTS) and Connect.Everything, and expansion of several efforts supporting precision, navigation and timing and electromagnetic spectrum dominance.

C. Accomplishments/Planned Programs ($ in Millions)

	FY 2015	FY 2016	FY 2017
Title: Adaptive Radio Frequency Technology (ART)	24.003	16.550	8.500

Description: There is a critical ongoing military need for flexible, affordable, and small size, weight and power (SWaP) real-time-adaptable military electromagnetic interfaces. The Adaptive Radio Frequency Technology (ART) program will provide the warfighter with a new, fully adaptive radio platform capable of sensing the electromagnetic and waveform environment in which it operates, making decisions on how to best communicate in that environment, and rapidly adapting its hardware to meet ever-changing requirements, while simultaneously significantly reducing the SWaP of such radio nodes. ART technology will also provide each warfighter, as well as small-scale unmanned platforms, with compact and efficient signal identification capabilities for next-generation cognitive communications, and sensing and electronic warfare applications. ART technology will also enable rapid radio platform deployment for new waveforms and changing operational requirements. The project will remove the separate design tasks needed for each unique Radio Frequency (RF) system, which will dramatically reduce the procurement and sustainment cost of military systems. ART aggregates the Feedback Linearized Microwave Amplifiers program, the Analog Spectral Processing program, and Chip Scale Spectrum Analyzers (CSSA) program, and initiates new thrusts in Cognitive Low-energy Signal Analysis and Sensing Integrated Circuits (CLASIC), and Radio-Frequency Field-Programmable Gate Arrays (RF-FPGA).

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
FY 2015 Accomplishments: - Demonstrated a radio reconfigurable between five different RF systems using integrated phase-change switch and silicon germanium (SiGe) technologies. Phase change switch reliability improved to 400,000 cycles and power handling improved by 10X to nearly 1 watt. - Integrated a highly reconfigurable RF front-end into a commercial software defined radio board that broadened the user base for RF-FPGA technology and transitioned multiple RF-FPGA cognitive radios. - Demonstrated the ability to, without prior knowledge, classify 32 wireless communication signal types in a hand held form factor while consuming less than 10 mW of power. - Demonstrated an adaptable, fully integrated radio system that is small enough to be carried by a warfighter and is resistant to jamming. ***FY 2016 Plans:*** - Investigate transition paths for phase change switch technology including potential transitions into a commercial semiconductor foundry. - Investigate transition paths for RF-FPGA reconfigurable RF front-ends including supplying demo units to DoD end users and investigating commercial paths for suppling the technology to the DoD. - Increase power handling of phase change switch technology to > 1W and improve reliability to > 1 Million cycles to meet the performance requirements of military and commercial communications systems. - Demonstrate an RF front-end reconfigurable between five different RF systems with performance approaching (> 90%) that of a fixed point solution. ***FY 2017 Plans:*** - Finalize transition plans for a fully reconfigurable RF circuit technology at the component and system levels.			
Title: Diverse & Accessible Heterogeneous Integration (DAHI) ***Description:*** The scaling of silicon (Si) transistors to ever smaller dimensions has led to dramatic gains in processor performance over the past fifty years. In parallel, Integrated Circuits (IC) designers for RF circuits have leveraged the different material properties of compound semiconductor (CS) technologies such as indium phosphide (InP), gallium arsenide (GaAs), gallium nitride (GaN) and silicon-germanium (SiGe) to enable devices that operate at frequencies and powers difficult or impossible to achieve in Silicon. Historically, a designer would have to decide between the high density of Si circuits or the high performance of CS materials. Prior DARPA efforts have demonstrated the ability to achieve near-ideal "mix-and-match" capability for DoD circuit designers with limited demonstrations of the heterogeneous integration of silicon and InP technologies that far exceeded what can be accomplished with one technology alone. Specifically, the Compound Semiconductor Materials On Silicon (COSMOS) program enabled transistors of InP to be freely mixed with silicon complementary metal-oxide semiconductor (CMOS) circuits to obtain the benefits of both technologies (very high speed and very high circuit complexity/density, respectively). The Diverse &	29.400	16.983	11.500

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E *I ELECTRONICS TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Accessible Heterogeneous Integration (DAHI) effort will take this capability to the next level, ultimately offering the seamless co-integration of a variety of semiconductor devices (for example, GaN, InP, GaAs, antimonide based Compound Semiconductors), microelectromechanical (MEMS) sensors and actuators, photonic devices (e.g., lasers, photo-detectors) and thermal management structures. This capability will revolutionize our ability to build true "systems on a chip" (SoCs) and allow dramatic size, weight and volume reductions while enabling higher performance such as power, bandwidth or dynamic range in our electronic systems for electronic warfare, communications and radar. In the Applied Research part of this program, high performance RF/optoelectronic/mixed-signal systems-on-a-chip (SoC) for specific DoD transition applications will be developed as a demonstration of the DAHI technology. To provide maximum benefit to the DoD, these processes will be transferred to a manufacturing flow and made available (with appropriate computer aided design support) to a wide variety of DoD laboratory, Federally Funded Research and Development Center (FFRDC), academic and industrial designers. Manufacturing yield and reliability of the DAHI technologies will be characterized and enhanced. This program has advanced technology development efforts funded in PE 0603739E, Project MT-15. ***FY 2015 Accomplishments:*** - Completed first run development of new CMOS-compatible processes to achieve heterogeneous integration with diverse types of compound semiconductor transistors, MEMS, and non-silicon photonic devices, including interconnect and thermal management approaches. - Developed wafer-bonding-based and assembly-based heterogeneous integration process technology, enabling the design of demonstration circuits. - Completed first manufacturing run demonstrating yield and reliability enhancement for multi-user foundry capability based on developed diverse heterogeneous integration processes. - Successfully created circuits using the DAHI process that represent a variety of next generation systems, such as radar, EW, and communications. These include Gallium Nitride (GAN) -Indium Phosphide (InP) differential and push-pull amplifiers, heterogeneously integrated RF/optoelectronic circuits, and integrated polyphase transmitter and voltage-controlled oscillator-amplifier chains using silicon CMOS, InP Heterojunction Bipolar Transistor (HBTs), and GaN High-Electron-Mobility Transistor (HEMTs). ***FY 2016 Plans:*** - Demonstrate heterogeneous integration of advanced node silicon CMOS processes achieved with diverse types of compound semiconductor transistors, MEMS, and non-silicon photonic devices, including interconnect and thermal management approaches. - Transition multi-user foundry interface to independent design service from proprietary foundry model to enable community access to diverse heterogeneous integration processes.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E I *ELECTRONICS TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Demonstrate sustainable model and accessibility via foundry/customer engagements, including detailed cost models and quotations. ***FY 2017 Plans:*** - Demonstrate heterogeneous integration process variant based on low cost Si 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: Common Heterogeneous integration & IP reuse Strategies (CHIPS)* ***Description:*** *Formerly Fast and Big Mixed-Signal Designs (FAB) The scaling of silicon transistors to ever smaller dimensions has led to dramatic gains in processor performance over the past forty years. In parallel, IC designers for RF circuits have leveraged the different material properties of compound semiconductor (CS) technologies such as gallium arsenide (GaAs), gallium nitride (GaN) and silicon-germanium (SiGe) to enable devices that operate at frequencies and powers difficult or impossible to achieve in silicon. When integrated together the heterogeneous integration of these technologies has been demonstrated to far exceed what can be accomplished with any one technology alone. The process of integrating CS technologies on silicon currently requires that the silicon transistor dimension, or process node, be fixed which requires designs to be remade for various combinations of technology and process node, a costly and time consuming effort. This program will investigate the potential for a truly process-agnostic integration technology that is inclusive of any current or future circuit fabrication technology with a standardized interconnect topology. Such a technology platform will enable the design of individual circuit intellectual property (IP) blocks, such as low-noise amplifiers or analog-to-digital converters (ADC), with a goal of re-using them across applications and resulting in time and cost savings. Re-use will allow the DoD to spread the upfront design cost of these blocks over several designs instead of leveling the burden on a single program. Furthermore, the IP can be designed in the fabrication process best suited for the performance goals and evolve more quickly than larger, more expensive single-chip (monolithic) systems-on-a-chip. Through standardization of the interface, CHIPS will enable the DoD to leverage the advancements driven by the global semiconductor market rather than relying on a single on-shore foundry provider or on proprietary circuit designs owned by a few traditional prime performers. In the Applied Research part of this program, focus will be placed on the rapid development and insertion of microsystems utilizing the CHIPS technology. For example, the development of an ADC combining a SiGe circuit integrated with 14 nanometer Silicon CMOS will be explored. This program has advanced technology development efforts funded in PE 0603739E, Project MT-15. ***FY 2015 Accomplishments:***	4.823	14.800	25.500

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
- Determined the best choices for the RF and digital technologies and the best methods of co-integration (monolithic, through-silicon via (TSV) and interposer) in order to achieve program objectives, along with identifying partner(s) for fabrication and/or integration. - Began circuit design activities to determine performance benefits of new processes enabled by the program. - Studied the best technology for various RF functional blocks for optimal use of mixed technologies. - Investigated a methodology for enabling reuse of government funded or commercial IP and mechanisms for storing them for future use. - Initiated studies that investigated the benefits to development cycle and cost reduction for electronics IC s through internal IP reuse at a large defense contractor. ***FY 2016 Plans:*** - Continue to investigate choices for the RF and digital technologies and the best methods of co-integration (monolithic, through-silicon via (TSV) and interposer) in order to achieve program objectives, along with identifying partner(s) for fabrication and/or integration. - Continue to study the best technology for various RF functional blocks for optimal use of mixed technologies. - Investigate tradeoff matrix for various co-integration (monolithic, through-silicon via (TSV) and interposer) strategies for RF and digital technologies. - Develop a cost model to analyze the impact of IP reuse using insight gained from large defense contractor development cycle study. - Study the system level impact of IP re-use for the optimal use of RF mixed technology functional blocks. ***FY 2017 Plans:*** - Finalize potential standards definitions for high-bandwidth interfaces of CMOS chiplet-to-chip interconnections. - Study the system level impact of IP re-use for the optimal use of RF mixed technology functional blocks. - Initiate circuit demonstrations of chip-to-chip interconnects for CMOS chip stacks. - Initiate circuit demonstrations with heterogeneous integration of DOD IP blocks and commercial IP blocks. - Continue circuit design activities to determine performance benefits of new processes enabled by the program.			
Title: Direct On-Chip Digital Optical Synthesis (DODOS) ***Description:*** The development of techniques for precise frequency control of RF and microwave radiation in the 1940's revolutionized modern warfare. Frequency control is the enabling technology for RADAR, satellite and terrestrial communications, and positioning and navigation technology, among many other core DoD capabilities. By comparison, frequency control at optical frequencies is relatively immature, comparable to the state-of-the-art of microwave control in the 1930's. The first practical demonstration of optical frequency synthesis, utilizing a self-referenced optical comb, was performed in 1999 and, since that time, the precision and accuracy of optical measurements has improved by four orders of magnitude, including the demonstration of	3.664	9.400	13.000

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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 2015	FY 2016	FY 2017
atomic clocks utilizing optical-frequency atomic transitions that far outperform existing technology based on microwave transitions. To date, however, optical frequency control has been constrained to laboratory experiments due to the large size, relative fragility, and high cost of optical comb-based synthesizers. Recent developments in self-referenced optical frequency combs in microscale resonators enable the development of a fully-integrated chip-scale optical frequency synthesizer. Ubiquitous low-cost robust optical frequency synthesis is expected to create a similar disruptive capability in optical technology as microwave frequency synthesis did in the 1940's, enabling high-bandwidth coherent optical communications, coherent synthesized-aperture LiDAR, portable high-accuracy atomic clocks, high-resolution standoff gas/toxin detection, and intrusion detection, among other foreseen applications. The Direct On-chip Digital Optical Synthesis (DODOS) program will integrate a diverse range of photonic and electronic components to create a microscale, high-accuracy optical frequency synthesizer, in a compact, robust package, suitable for deployment in a wide variety of mission-critical DoD applications. Significant challenges in the program include the integration of heterogeneous devices and materials that are incompatible with conventional high-volume manufacturing of integrated circuits, optimizing efficient on-chip pump lasers and high-bandwidth detectors, and developing high-precision microwave control electronics with low power consumption. Basic research for this program is funded within PE 0601101E, Project ES-01. ***FY 2015 Accomplishments:*** - Completed modeling and proof-of-concept experiments to validate low-threshold approaches to optical frequency combs. - Developed DODOS system architectures and integration approaches. ***FY 2016 Plans:*** - Validate 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. - Prototype critical photonic components in processes consistent with subsequent co-integration. - Demonstrate tabletop DODOS, utilizing microscale components compliant with Phase-1 Program objectives. ***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.			
Title: Arrays at Commercial Timescales (ACT) ***Description:*** Phased arrays are critical system components for high performance military electronics with widespread applications in communications, electronic warfare and radar. The DoD relies heavily on phased arrays to maintain technological superiority in nearly every theater of conflict. The DoD cannot update these high cost specialized arrays at the pace necessary to effectively	25.000	26.550	20.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
counter adversarial threats. The Arrays at Commercial Timescales (ACT) program fills this gap through the use of commercial-of-the-shelf components that can undergo technology refresh far more frequently in response to a continually changing threat environment. ACT will develop adaptive and standardized digital-at-every-element arrays that can replace static analog beamformers with cost effective digital array systems capable of a yearly technology refresh. By doing so, phased arrays will become ubiquitous throughout the DoD, moving onto many platforms for which phased arrays had been previously prohibitively expensive to develop or maintain. ***FY 2015 Accomplishments:*** - Continued development and integration of common hardware components, such as application specific integrated circuits and field programmable gate arrays, for a wide range of phased array antenna systems; finalized initial designs and began fabrication for ACT demonstration units to be completed and tested in FY16. - Signed Memorandum of Understanding (MOU) between the Army Research Lab (ARL) and DARPA to support the performance testing of ACT Common Modules for potential Army transition opportunities. - Continued to identify government application spaces and transition paths for the ACT Common Module and reconfigurable antenna apertures to include the planned use of ACT technology components in a new AFRL program. - Finalized design and started fabrication of application specific integrated circuits (ASIC) in 32 nanometer (nm) CMOS, 65 nm CMOS and Silicon Germanium (SiGe) technologies that enable commonality across a wide range of phased array platforms. - Performed first measurements on fabricated SiGe ASICS demonstrating RF filter performance and RF amplifier performance as predicted by modeling. ***FY 2016 Plans:*** - Demonstrate Common Module hardware viability through government testing of delivered hardware components in a government furnished system platform. - Organize an ACT common module demonstration day to inform potential transition partners and industrial users on the measured performance of the Phase I modules. - Investigate the benefits of and develop plans and preliminary designs for upgrading the ACT Common Module in a state-of-the-art fabrication process. - Demonstrate a fundamental element of a reconfigurable antenna array and define a list of personalities possible to cover the DoD application space. - Continue to identify government application spaces and transition paths for the ACT Common Module and reconfigurable antenna apertures. ***FY 2017 Plans:*** - Develop the ACT common module using an advanced process node and demonstrate the performance improvement compared to the common module developed with an earlier node in Phase I.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E *I ELECTRONICS TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- 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 antenna array using 16 elements that cover multiple frequency bands (S, X bands) using the technology demonstrated earlier in the program.			
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC)	-	12.000	18.000
Description: The effectiveness of combat operations across all domains increasingly depends on our ability to control and exploit the electromagnetic (EM) spectrum, and to deny its use to our adversaries. Below 30 GHz, the proliferation and availability of inexpensive high-power commercial RF sources has made the EM spectrum crowded and contested, challenging our spectrum dominance. The numerous tactical advantages offered by operating at higher frequencies, most notably the wide bandwidths available, is driving both commercial and DoD solid-state and vacuum electronic amplifiers into the millimeter wave (mm-wave) spectrum above 30 GHz. Control of the mm-wave spectrum necessitates advanced and increasingly more sophisticated electronic components and systems. The performance of these systems strongly depends on the available amplifier power which impacts how much power the system can radiate. The High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) program seeks to strengthen our dominance of the EM spectrum and create overmatch capability by developing a new class of wideband, high-power vacuum electronic amplifiers. The size, weight, and power (SWaP) will be consistent with reusable airborne and mobile platforms enabling an increased offset range and the ability to engage multiple targets at the speed of light. Realization of wideband, high power vacuum electronic amplifier technology will require significant advancements in cathodes with high current-density and long lifetime, beam-wave interaction circuits with wide bandwidth and high power handling capability, wideband and low-loss vacuum windows, and compact magnetic structures for electron beam transport. The HAVOC amplifier will provide leap-ahead capabilities to air, ground, and ship-based communications, sensing, and electronic warfare systems. Opportunities for transfer of the HAVOC technology to the Services will be identified during the execution of the early phases of the program. The 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 Plans:*** - Initiate the design and modeling of a wide-bandwidth, high power mm-wave vacuum electronic amplifier. - Identify 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.			

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- 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. ***FY 2017 Plans:*** - 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. - 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) ***Description:*** The DoD relies on GPS for ubiquitous and accurate positioning, navigation, and timing (PNT). With the increased prevalence of intentional GPS jamming, spoofing, and other GPS-denial threats, GPS access is increasingly unavailable in contested theaters and alternative sources of PNT are required. In particular, guided munitions navigation is the most immediate and among the most demanding of GPS-denial challenges, due to the necessity of operating in highly contested theaters and the stringent requirements for minimization of cost, size, weight, and power consumption (CSWaP). The Precise Robust Inertial Guidance for Munitions (PRIGM) program will develop low-CSWaP inertial sensor technology for GPS-free munitions navigation. PRIGM comprises two focus areas: 1) Development of a Navigation-Grade Inertial Measurement Unit (NGIMU) that transitions state-of-the-art MEMS to DoD platforms by 2020; and 2) Research and development of Advanced Inertial MEMS Sensors (AIMS) to achieve gun-hard, high-bandwidth, high dynamic range navigation requirements with the objective of complete autonomy in 2030. PRIGM will advance state-of-the-art MEMS gyros from TRL-3 devices to a TRL-6 transition platform (complete IMU) that enables Service Labs to perform TRL-7 field demonstrations. PRIGM will exploit recent advances in heterogeneous integration of photonics and CMOS and advanced MEMS technology to realize novel inertial sensors for application in extreme dynamic environments and beyond navigation-grade performance. Future warfighting scenarios will take place in a GPS-denied world. High-dynamics navigation applications, such as smart munitions, require low-CSWaP inertial sensors demonstrating high bandwidth, high precision, and high shock tolerance. Conventional MEMS inertial sensors rely on capacitive sensing to measure position, which suffer from perturbations due to asymmetry, temperature sensitivity, parasitic capacitances, and squeeze film damping of gas in narrow gaps. Various methods have been proposed to overcome challenges with capacitive readout. One solution is optical sensing, which has demonstrated high sensitivity, low noise position sensing and potential to reject external vibrations. Recent advances in heterogeneous	-	10.000	21.911

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
integration, on-chip optical waveguides, and quantum-assisted sensing and readout of MEMS/NEMS have resulted in new capabilities to enable candidate technologies for PRIGM. The candidate technologies include optically interrogated MEMS gyroscopes and accelerometers, waveguide optical gyroscopes, and rate-integrating MEMS gyroscopes. Basic research for this program is funded within PE 0601101E, Project ES-01 and advanced development for the program is budgeted in PE 0603739E, Project MT-15. ***FY 2016 Plans:*** - Model and design architectures for chip-scale, waveguide optical gyroscopes, which combine the essential components and functionality of ring-laser into a photonic integrated circuit. - Model and design optically interrogated MEMS inertial sensors, leveraging the high sensitivity of optical interrogation with the precision machining and low-CSWaP enabled by MEMS. - Develop processes for co-fabrication of MEMS and photonic integrated circuits. - Design and simulate photonic and MEMS-photonic sensors suitable for high shock survival. ***FY 2017 Plans:*** - Integrate component technology and demonstrate integrated photonic-MEMS inertial sensors with beyond navigation grade performance. - 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) ***Description:*** The DoD has an unfilled need for a persistent, event driven sensing capability, where physical, electromagnetic and other sensors can be pre-placed and remain dormant until awoken by an external trigger or stimulus. State-of-the-art sensors use active electronics to monitor the environment for the external trigger. The power consumed by these electronic circuits limits the sensor lifetime to durations of weeks to months. The Near Zero Power RF and Sensor Operations (N-ZERO) program will extend the lifetime of remotely deployed sensors from months to years. N-ZERO will develop the underlying technologies and demonstrate the capability to continuously and passively monitor the environment and wake-up an electronic circuit upon detection of a specific signature or trigger. Thereafter, sensor lifetime will be limited only by processing and communications of confirmed events. The N-ZERO program will replace the power consuming electronic circuits used for processing and detection of information in current systems with passive or extremely low power devices. The N-ZERO program will develop RF communications and physical sensor systems that collect, process, and detect the presence of useful information, while rejecting spurious signals and noise, using the energy in the collected information to perform these functions. This will eliminate or significantly reduce the standby power consumption from the battery. By doing so, the N-ZERO program will provide the warfighter with wireless sensors	-	4.500	13.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
systems with drastically increased mission life. The basic research component of this program is budgeted under PE 0601101E, Project ES-01. ***FY 2016 Plans:*** - Design and fabricate 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. - Design and fabricate hardware components and microsystems for detecting and discriminating the presence of a specific machine at a distance of 0.5 m while consuming less than 10 nW of power consumption. - Identify government application spaces and transition paths that will make use of N-ZERO detection and signal processing. ***FY 2017 Plans:*** - Evaluate the detection performance and power consumption of the RF and physical sensor microsystems. - 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) signal strength. - Identify and engage potential users in the National Security space to develop N-ZERO transition opportunities.			
Title: Wafer-scale Infrared Detectors (WIRED)* ***Description:*** *Formerly Microwaves and Magnetics (M&M) Leveraging investments in high-volume wafer scale processing has made digital imaging technologies ubiquitous, for example, making high resolution digital cameras common place in every cell phone. A smaller scale revolution is currently underway due to the development of long-wave infrared (LWIR) thermal imaging sensors. These sensors are also manufactured at the wafer scale, and they are becoming widely available due to the low cost relative to existing infrared (IR) imaging technologies. No similar technology exists in the tactically and strategically important short-wave and mid-wave IR (SWIR/MWIR) bands. The Wafer-scale Infrared Detectors (WIRED) program addresses these needs by developing high performance SWIR and MWIR Focal Plane Array (FPA) technologies that are manufactured at the wafer scale. These sensors will provide increased standoff distances to smaller Tier I and II class unmanned aerial vehicle platforms, low cost missiles, hand held weapon sights/handheld surveillance systems, helmet-mounted systems, and ground vehicle-mounted threat warning systems. The MWIR detector technologies developed under WIRED will provide, for the first time, MWIR FPAs that do not require heavy, expensive cryogenic coolers. The SWIR detector technologies will provide, for the first time, diffraction limited imaging with compact optics. Significant challenges include obtaining high detector performance from disordered materials that can be deposited directly onto readout integrated circuits (ROICs). New ROIC designs will also be required to achieve the noise reduction and pixel pitches required for the suggested applications.	-	6.000	13.500

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
FY 2016 Plans: - Explore fundamental properties of disordered materials, and evaluate the processes that affect sensor performance at elevated operating temperatures. - Develop and evaluate MWIR sensor technology that is compatible with wafer-scale processing, and demonstrates high performance at operating temperatures compatible with low-cost thermoelectric coolers. - Develop and evaluate SWIR sensor technology that is compatible with wafer-scale processing, and provides an architecture which will scale 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. - Demonstrate imaging from MWIR detectors that are integrated directly onto 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.			
Title: Modular Optical Aperture Building Blocks (MOABB)* ***Description:*** *Formerly MultiPLEX While radio-enabled technologies manipulate radio waves for sensing (e.g. RADAR) and communication, optical systems leverage visible light and can enable foliage-penetrating light detection and ranging (LIDAR), navigation, 3D imaging, and long-range communications. Although the basic technology already exists, optical systems have been limited by their size, weight, and cost. A traditional optical telescope, for instance, requires expensive precision lenses and mirrors, large empty volumes for gathering and focusing light, and heavy mechanical steering components. Mechanical steering's limited speed and precision also impedes the use of optical systems in certain defense applications, although LIDAR is more suitable for detailed imaging relative to RADAR. The Modular Optical Aperture Building Blocks (MOABB) program seeks to greatly reduce the size and weight of optical systems while increasing steering rates. Specifically, MOABB aims to construct millimeter scale optical unit cells that can be coherently arrayed onto a flat surface to form a much larger, higher power device. These building blocks would replace the precision lenses, mirrors, and mechanical components from a conventional optical system. MOABB would also develop scalable optical phased arrays, borrowing from RADAR the technology required to steer electromagnetic waves, such as light and radio, without mechanical components. These advances would allow for a 100-fold reduction in size and weight and a 1,000-fold increase in steering rate. For applications such as LIDAR, laser communications and laser illumination, MOABB provides a compelling opportunity to replace empty space and bulk components with a planar, integrated system.	-	8.000	15.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
FY 2016 Plans: - Design and simulate non-mechanically steered millimeter-scale transmit and receive unit cells with 5mW of output power. - Perform 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. - Simulate low-loss grating design.			
Title: Circuit Realization At Faster Timescales (CRAFT)* ***Description:*** *Formerly Diamond Enhanced Devices (DiamEnD) High performance electronics are at the heart of most modern military systems. Today, when selecting the electronics for advanced systems, DoD programs must choose between a high performing, custom integrated circuit that takes years to design, or a significantly lower performing general purpose integrated circuit that can be designed in a few months. The tradeoff between performance and time has placed the DoD in an undesirable state. The Circuit Realization At Faster Timescales (CRAFT) Program will break this paradigm by developing a custom integrated circuit design flow and methodology that will drastically reduce the amount of effort required to design a custom integrated circuit by 10 times while preserving high performance. CRAFT will enable critical DoD electronic system needs by reducing the barrier to the design and fabrication of custom integrated circuits in leading-edge CMOS technology. The CRAFT program will investigate novel design flows that utilize recent advances in software development methodology to reduce the amount of required design time. The goal will be a reduction in the manual labor required for verification by automating much of the design tasks with automated generators. In addition, CRAFT will explore increasing the level of design reuse and the flexibility of transferring a design from one foundry to another as well as migrating from one foundry technology to a more advanced technology. ***FY 2016 Plans:*** - Complete design submissions for the first Fin Field Effect Transistor (FinFET) multi-project wafer shuttle run. - Define the initial architecture of the proposed object-oriented design flows. - Initiate effort to establish 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 and evaluate the first two FinFET multi-project wafer shuttle runs.	-	9.000	21.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E I *ELECTRONICS TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Initiate efforts to transfer design elements between foundries and across technology nodes. - Complete initial testing of at least two full object oriented design flows.			
Title: Atomic Clock with Enhanced Stability (ACES)* ***Description:*** *Formerly Next Generation Atomic Clock Atomic clock technology provides the high-performance backbone of timing and synchronization for DoD navigation, communications, Intelligence Surveillance and Reconnaissance (ISR), and Electronic Warfare (EW) systems. Prior DARPA investment in Chip-Scale Atomic Clock (CSAC) technology has led to recent demonstrations of enhanced DoD capabilities, enabled by the availability of atomic-quality timing in portable battery-powered applications. The Atomic Clock with Enhanced Stability (ACES) program will develop a next-generation low-size, weight, and power (SWaP) atomic clock, with 100X-1000X improvement in key performance parameters, by employing alternative approaches to atomic confinement and interrogation, with particular focus on developing the component technologies necessary to enable low-cost manufacturing and robust deployment in harsh DoD environments. ACES will develop chip-scale atomic clocks achieving temperature coefficient of frequency < 10^-15/°C, drift < 10^-13/month, instability < 10^-11/sqrt(tau), and retrace < 10^-13 which are robust against acceleration and magnetic fields (10^-13/g and 10^-13/gauss, respectively). This will enable precise timing on low size, weight, and power (SWaP) platforms with extended mission duration. In order to achieve these performance metrics, new enabling technology and interrogation techniques will be integrated into systems. ***FY 2016 Plans:*** - Begin modelling and simulation to support architecture development of the ACES device. ***FY 2017 Plans:*** - Perform Laboratory demonstration of functioning clock of the ACES architecture. - Develop and verify low-SWaP physics package components consistent with proposed performance and overall physics package power consumption of <250 mW. - Demonstrate a breadboard atomic clock physics package with power consumption < 250 mW, instability of less than 10^-11/ sqrt(tau), and frequency retrace of less than 10^-11. - Develop and design an integrated physics package with overall volume of < 30cm^3 and power consumption of <250 mW.	-	5.000	14.000
Title: Limits of Thermal Sensors (LOTS) ***Description:*** The long wave infrared (LWIR) is the most commonly used spectral band for thermal imagery, and current systems must choose between high performance cryogenically cooled focal plane arrays (FPAs), and uncooled microbolometers.	-	-	9.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
Microbolometers offer a significant reduction in size, weight, and cost (SWaP-C), at the expense of reduced sensitivity and slower response time. The objective of the LOTS program is to demonstrate a detector technology that breaks this traditional trade space by providing the same benefits in SWaP-C as current microbolometers while approaching the sensitivity of a cryogenically cooled sensor. The result will be the ability to deploy smaller, lighter, cheaper sensors on higher value assets and in more critical missions. ***FY 2017 Plans:*** - Demonstrate at least 3x performance improvement in uncooled microbolometers over current production performance. - Demonstrate sensor fabrication in a production environment.			
Title: Connect.Everything ***Description:*** The Connect.Everything program will focus on the fielding of low-power, intelligent communication modules with high functionality density to enable ubiquitous connectivity. Research efforts will focus on leveraging commercial industry investment in future wireless technology to develop communication modules that operate within the various unlicensed radio frequency (RF) and millimeter wave (mm-wave) frequency bands. Employing advanced silicon technology, a fully-integrated multi-channel transceiver array including antenna, RF front-end amplifiers, passives, modems, and digital processors will be realized with a goal of reducing the barrier of connecting an existing device into a high data rate network. These universal communication modules will be capable of accepting digital input data and DC power only, modulating the digital data and generating RF/mm-wave radio signals, and receiving and demodulating external RF/mm-wave radio signals into digital output data. More importantly, built-in calibration, tuning, and self-test functions will be integrated so that the communication module will not require costly post-manufacture testing and evaluation. The program will extend current state of art Multiple-Input Multiple-Output (MIMO) techniques toward future applications which require gigahertz bandwidth, low latency, low power, and high power efficiency to support seamless connectivity between users, sensors, payloads, and platforms across the RF and mm-wave spectrum. ***FY 2017 Plans:*** - Develop a design concept for a fully-integrated, multi-channel communication module with embedded radio circuitry and digital processing capability to enable digital-in-to-RF transmitters and RF-in-to-digital-out receivers on a single integrated circuit. - Design a subset of the critical RF/mm-wave and digital circuits that enhance the functionality of the communication module. - Evaluate the communication capabilities, limitations, power consumption, and output power as well as spectrum efficiency of the communications module using modeling and simulation tools.	-	-	9.000
Title: IntraChip Enhanced Cooling (ICECool)	18.000	4.750	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
Description: The IntraChip Enhanced Cooling (ICECool) program is exploring disruptive technologies that will remove thermal barriers to the operation of military electronic systems, while significantly reducing size, weight, and power consumption. These thermal barriers will be removed by integrating thermal management into the chip, substrate, or package technology. Successful completion of this program will raise chip heat removal rates to above 1 kW/cm^2 and chip package heat removal density to above 1kW/cm^3 in RF arrays and embedded computers. Specific areas of focus in this program include overcoming limiting evaporative and diffusive thermal transport mechanisms at the micro/nano scale to provide an order-of-magnitude increase in on-chip heat flux and heat removal density, determining the feasibility of exploiting these mechanisms for intrachip thermal management, characterizing the performance limits and physics-of-failure of high heat density, intrachip cooling technologies, and integrating chip-level thermal management techniques into prototype high power electronics in RF arrays and embedded computing systems. ***FY 2015 Accomplishments:*** - Demonstrated the full implementation of the fundamental building blocks of evaporative intrachip cooling including embedded micron-scale microfluidic channels with pin fins in 3D Silicon (Si) chips with two-phase flow approaching 90% vapor exit quality. - Demonstrated High Power Amplifiers (HPA) thermal test vehicles with thermal resistance reduced by 3x compared to the State of the Art (SoA) that successfully handled die-level heat fluxes of 1 kW/cm2 and transistor hot spots fluxes of 30 kW/cm2 as well as embedded High Performance Computers (HPC) thermal test vehicles that successfully handled hot spot fluxes of 2 kW/cm2. - Designed application-oriented electrical test vehicles to demonstrate the performance benefits of embedded microfluidic cooling and related these results to system-level performance and size, weight, power and cost (SWaPC) benefits to DoD programs-of-record through the use of intrachip thermal management technologies. - Designed fully-functional HPAs and HPCs to demonstrate the thermal and electrical performance benefits of embedded microfluidic cooling where the reduction in thermal resistance will enable a 3x or greater increase in output power (HPAs) or computational performance (HPCs) compared to the State of the Art (SOA) baseline. ***FY 2016 Plans:*** - Perform reliability testing of ICECool electrical demonstration modules to establish mean time to failure and compatibility with relevant Military specifications. - Test and demonstrate fully-functional HPAs with a 3x or greater increase in output power over the baseline GaN-on-SiC approach. - Design application-ready ICECool modules and subarrays to facilitate transition of ICECool enabled components into relevant systems.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
- Engage in transition activities for the ICECool technology to include insertion of ICECool enabled components in relevant subsystems such as transmit/receive modules and embedded airborne computing platforms.			
Title: In vivo Nanoplatforms (IVN) ***Description:*** The In vivo Nanoplatforms (IVN) program seeks to develop 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 to be developed will enable continuous in vivo monitoring of both small (e.g., glucose, nucleic acids, biomarkers) and large molecules (e.g., biological threat agents). A reprogrammable therapeutic platform that targets gene regulatory sequences will enable 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 include safety, toxicity, biocompatibility, sensitivity, response, and targeted delivery. The IVN program will have diagnostic and therapeutic goals that enable a versatile, rapidly adaptable system to provide operational support to the warfighter in any location. ***FY 2015 Accomplishments:*** - Demonstrated broad capability of in vivo nanoplatform sensors to detect additional military-relevant analytes (e.g., pH, cortisol) in an animal model with a robust signal. - Demonstrated broad capability of in vivo nanoplatform therapeutics targeting gene regulatory sequences to maintain force health and reduce additional military-relevant pathogens or disease cofactors (e.g., multi-drug resistant bacteria, neurological disease) in an animal model. - Updated regulatory approval pathway with results from animal model safety and efficacy testing. ***FY 2016 Plans:*** - Demonstrate enhanced therapeutic performance via molecular targeting approaches in an animal model. - Demonstrate the ability of skin-based sensors to detect physiologically relevant molecules (e.g., pH, ions, glucose, lactate, and cortisol) in an animal model. - Demonstrate the ability of an in vivo nanoplatform to protect against infectious disease in an animal model. - Continue to update regulatory approval pathway with results from animal model safety and efficacy testing.	14.500	9.765	-
Title: Pixel Network (PIXNET) for Dynamic Visualization ***Description:*** The PIXNET program addresses the squad level capability gap for target detection, recognition and identification in day/night missions through real-time fusion of visible and thermal infrared (IR) imagery. The vision of the program is to offer the warfighter a small and versatile camera that would be affordable for individual soldiers and provide multiple band imagery with fusion capability to take full advantage of different wavelength-band phenomenology in a compact single unit. In the future, the availability of the PIXNET camera would enable a peer-to-peer networked system for image sharing within a squad, thereby providing a better common operating picture of the battlefield and significantly enhancing the warfighter's situational	13.000	9.500	-

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
understanding. The program aims to develop a low size, weight and power (SWaP), low cost, soldier-portable multiband infrared camera that will provide real-time single and multiple band imagery using a combination of a thermal and reflected spectral band. The use of fused imagery in the PIXNET design will allow the soldier to detect camouflaged targets and distinguish targets from decoys. The PIXNET camera will eliminate limitations posed by current camera systems, allowing for the detection, recognition and identification of targets from a single camera in daylight or no-light conditions. The PIXNET program will focus on a significant reduction in SWaP and cost of infrared sensor components to enable the deployment of this technology to a wide range of participants in the theater. The emphasis on a small form factor will enable new opportunities such as surveillance with small Unmanned Aerial Vehicles (UAV), multi-band rifle sights, vehicle-mounted systems, as well as helmet-mounted and handheld surveillance systems. The phenomenology of utilizing the unique characteristics of different infrared wavelengths for target detection will be exploited. The combination of a smart phone and PIXNET camera at the soldier level will enable more effective tactics, techniques and procedures (TTP) over the current capability. The PIXNET program takes advantage of the computing capability of smart phones to process and fuse multicolor images and send them as videos or still images to the warfighter's helmet-mounted display via a wireless or wired connection. ***FY 2015 Accomplishments:*** - Demonstrated brass board components for the visible and near infrared/long-wave infrared (VNIR/LWIR) helmet mounted camera. - Refined algorithms to fuse data from thermal and reflective bands with good image registration. - Completed data fusion demonstration and preliminary imaging for short-wave infrared/long-wave infrared (SWIR/LWIR) helmet mounted camera. - Completed prototype design for short-wave infrared/mid-wave infrared (SWIR/MWIR) clip-on weapon sight camera. - Achieved 99.8% operability with MWIR Focal Plane Array (FPA) base layer of the clip-on weapon sight camera. ***FY 2016 Plans:*** - Demonstrate the VNIR/LWIR camera and program completion. - Demonstrate the SWIR/LWIR helmet mounted camera on smart phone with real-time, on-board multi-band fusion and program completion. - Demonstrate bench-scale brassboard SWIR/MWIR camera with image fusion algorithms on an external laptop to demonstrate functionality. - Demonstrate final SWIR/MWIR clip-on weapon sight with on-board fusion and wireless transmission to a smart phone and program completion.			
Title: Vanishing Programmable Resources (VAPR)	5.500	9.000	9.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
Description: The Vanishing Programmable Resources (VAPR) program will create microelectronic and mechanical systems capable of physically disappearing (either in whole or in part) in a controlled, triggerable manner, a characteristic referred to as transience. The program will develop and establish an initial set of materials and components along with integration and manufacturing capabilities to undergird a fundamentally new class of electronics and mechanical structures defined by their performance and transience. These transient electronics and structural systems ideally should perform in a manner comparable to Commercial Off-The-Shelf (COTS) systems, but with limited device persistence that can be programmed, adjusted in real-time, triggered, and/or be sensitive to the deployment environment. Applications include sensors for conventional indoor/outdoor environments (buildings, transportation, and materiel), environmental monitoring over large areas, simplified diagnosis, treatment, and health monitoring in the field and airborne delivery vehicles with vanishing properties. VAPR will explore transience characteristics of electronic devices and structural materials as well as build out an initial capability to make transient electronics and transient structural materials a deployable technology for the DoD and Nation. The technological capability developed through VAPR will be demonstrated through two final test vehicles. The transient electronics test vehicle will be a vanishing sensor with RF link. The sensor with RF link will serve as an application vehicle showing the manufacturability of the research and process developed in the VAPR program being performed in PE 0601101E, Project TRS-01. The sensor with RF link is meant to be functional on its own, but also a leading indicator of the types of circuits possible under the VAPR program. The transient structural materials demonstration will be a vanishing air delivery vehicle capable of precise, gentle drops of small payloads (~3 lbs.). This demonstration will be functional on its own and will also be a leading indicator of the types of complex vanishing mechanical structures enabled by VAPR materials and technologies. The resulting prototype designs will establish a fundamental capability to gently, precisely, and without debris deliver mission-critical payloads and are expected to broadly apply to various concepts of operation (CONOPS) relevant to national security. ***FY 2015 Accomplishments:*** - Achieved a transience time of less than or equal to 5 minutes for simple electronic devices. - Reduced the variability of transience time to less than or equal to 90 seconds for simple electronic devices. - Demonstrated capability to operate foundry-fabricated transient electronic circuits and subsequent controlled transience. ***FY 2016 Plans:*** - Complete integration of transient devices and materials to form fully functional microsystems. - Achieve a transience time of less than or equal to 30 seconds for transient functional microsystems. - Improve the variability of transience time to less than or equal to 10 seconds. - Realize reliable operation of transient microsystems for greater than 100 hours after deployment, with subsequent controlled transience. ***FY 2017 Plans:***			

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
- Optimize novel transient materials for application in the air delivery vehicle, since it must meet structural and processing 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: Hyper-wideband Enabled RF Messaging (HERMES) ***Description:*** Modern weapons systems are dependent on radio frequency (RF) links for communications, command and control, geolocation and battle management. This dependence will only grow with the move to disaggregated systems in the battlefield. To create assured RF links in contested environments, HERMES will study the architectures and develop the technologies to enable spread-spectrum links with 10 GHz of instantaneous bandwidth. The ultimate objective is >70 dB of jammer suppression. This program will explore the limits of jammer suppression through a combination of processing gain and tunable filtering in a hyper-wideband system. ***FY 2015 Accomplishments:*** - Performed analysis and simulation of frequency-dependent channel propagation effects with associated mitigation methods. - Defined system architecture to include wireless RF transmitter and receiver architectures. - Tested prototype communication link demonstrating 6 GHz of instantaneous bandwidth and 25dB of jammer suppression. ***FY 2016 Plans:*** - Develop and test photonic-enabled wideband receivers for future scaling of link technologies with overall reduction of the system size, weight and power (SWaP). - Demonstrate a prototype broadband wireless communication link with 10 GHz of instantaneous bandwidth and 70dB of jammer suppression.	2.000	3.000	-
Title: Direct SAMpling Digital ReceivER (DISARMER) ***Description:*** The goal of the Direct SAMpling Digital ReceivER (DISARMER) program is to produce a hybrid photonic-electronic analog-to-digital converter (ADC) capable of coherently sampling the entire X-band (8-12 GigaHertz (GHz)). Conventional electronic wideband receivers are limited in dynamic range by both the electronic mixer and the back-end digitizers. By employing an ultra-stable optical clock, the DISARMER program will allow for mixer-less digitization and thereby improve the dynamic range 100x over the state of the art. Such a wide bandwidth, high fidelity receiver will have applications in electronic warfare and signals intelligence systems while dramatically reducing the cost, size and weight of these systems.	2.000	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
The DISARMER program will develop a low jitter mode-locked laser to be used as the sampling source. The program will also develop a novel photonic architecture in a compact platform capable of hybrid electronic-photonic track-and-hold functionality and coherent photo-detection. This program has advanced technology development efforts funded in PE 0603739E, Project MT-15. ***FY 2015 Accomplishments:*** - Demonstrated 5 femtosecond (fs) optical clock jitter in a compact mode-locked source. - Fabricated and tested the building block optical circuits for coherent demodulation of the optical signal. - Finalize fabrication and packaging of temperature stable laser module capable of 8 GHz repetition rate, 1 ps pulse width, and < 5 fs of integrated timing jitter. - Finalize fabrication and integration of photonic de-modulation module with high power photodiodes.			
Title: Micro-Technology for Positioning, Navigation, and Timing (Micro PN&T) ***Description:*** The Micro-Technology for Positioning, Navigation, and Timing (Micro-PNT) program developed low-Cost, Size, Weight, and Power (CSWaP) inertial sensors and timing sources for navigation in GPS degraded environments, primarily focusing on the development of miniature solid state and atomic gyroscopes and clocks. Both classes of sensors are currently unsuitable for small platform or dismount soldier applications. Micro Electro-Mechanical Systems (MEMS) sensors have limited performance but excellent CSWaP, while atomic sensors are capable of excellent performance but are limited to laboratory experiments due to complexity and high CSWaP. Micro-PNT advanced both technology approaches by improving the performance of MEMS inertial sensors and by miniaturizing atomic devices. Ultimately, low-CSWaP inertial sensors and clocks will enable ubiquitous guidance and navigation on all platforms, including guided munitions, unmanned aerial vehicles (micro-UAVs), and mounted and dismounted soldiers. The successful realization of Micro-PNT depends on development of new microfabrication processes and novel material systems for fundamentally different sensing modalities, as well as understanding the error sources at the microscale and the scaling relationships for size reduction of sensors based on atomic physics techniques. The Micro-PNT program included research into novel techniques for fabrication and integration of three-dimensional MEMS devices as well as theoretical and experimental studies of new architectures and geometries for MEMS inertial sensing. Atomic physics research included the development of new architectures for atomic inertial sensing and investigation of miniature enabling technologies, whose conventional counterparts are currently large, power hungry, and temperature sensitive, limiting high performance sensors to laboratory demonstrations. Advanced research for the program is budgeted in PE 0603739E, Project MT-12. ***FY 2015 Accomplishments:*** - Demonstrated on-chip MEMS calibration stages to track gyro bias and scale factor stability. - Demonstrated proof of concept sourcing and sinking of Rb for alkali vapor pressure control.	13.500	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
- Demonstrated ultra-narrow linewidth lasers. - Demonstrated waveguide modulation of on-chip lasers at atomic resonance wavelengths. - Demonstrated self-calibrating MEMS gyroscope with long-term scale factor and bias of < 10 parts per million (ppm) of full scale range.			
Title: Terahertz Electronics ***Description:*** The Terahertz Electronics program developed the critical semiconductor device and integration technologies necessary to realize compact, high-performance microelectronic devices and circuits that operate at center frequencies exceeding 1 Terahertz (THz). There are numerous benefits for electronics operating in the THz regime and new applications in imaging, radar, communications, and spectroscopy. The Terahertz Electronics program was divided into two major technical activities: Terahertz Transistor Electronics that included the development and demonstration of materials and processing technologies for solid-state transistors and integrated circuits for receivers and exciters that operate at THz frequencies; and Terahertz High Power Amplifier Modules that included the development and demonstration of vacuum electronic traveling wave tube (TWT) amplifiers for high power amplification of THz signals. ***FY 2015 Accomplishments:*** - Completed measurements of receiver/exciter technologies at and above 0.67 THz. - Demonstrated oscillator circuits at 1.03 THz. - Demonstrated a prototype THz transceiver link using THz indium phosphide high electron mobility transistor (HEMT) technology. - Demonstrated a 1.03 THz solid-state amplifier, the first time a solid state circuit has operationally crossed the THz barrier. - Demonstrated improved thermal performance of vacuum amplifier for high duty cycle operation at THz frequencies. - Demonstrated the first vacuum electronic traveling wave tube amplifier at 1 THz.	8.020	-	-
Title: Nitride Electronic NeXt-Generation Technology (NEXT) ***Description:*** To realize high performance analog, Radio Frequency (RF) and mixed-signal electronics, a next-generation transistor technology with high cutoff frequency and high breakdown voltage is under development. This technology enabled large voltage swing circuits for military applications that the current state-of-the-art silicon transistor technology cannot support. The objective of the NEXT program was to develop a revolutionary, wide band gap, nitride transistor technology that simultaneously provides extremely high-speed and high-voltage swing [Johnson Figure of Merit (JFoM) larger than 5 Terahertz (THz)-V] in a process consistent with large scale integration of enhancement/depletion (E/D) mode logic circuits of 1,000 or more transistors. In addition, this fabrication process was reproducible, high-yield, high-uniformity, and highly reliable. The accomplishment of this goal was validated through the demonstration of specific program Process Control Monitor (PCM) Test Circuits such as 5, 51 and 501-stage ring oscillators in each program phase. The impact of this next-generation nitride electronic	4.280	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
technology is the speed, linearity, and power efficiency improvement of RF and mixed-signal electronic circuits used in military communications, electronic warfare and sensing. ***FY 2015 Accomplishments:*** - Established the baseline of the high-speed / high breakdown voltage NEXT fabrication technology with high reproducibility and yield. - Designed, fabricated, and tested military-relevant circuits, such as millimeter-wave low noise amplifiers, power amplifiers and triplers, using the developed NEXT transistor technology. - Developed NEXT process design kit to allow circuit designers to utilize NEXT technology in other advanced circuit designs.			
Title: Microscale Plasma Devices (MPD) ***Description:*** The goal of the Microscale Plasma Devices (MPD) program was to design, develop, and characterize MPD technologies, circuits, and substrates. The MPD program focused on development of fast, small, reliable, high-carrier-density, micro-plasma switches capable of operating in extreme conditions, such as high-radiation and high-temperature environments. Specific focus was given to methods that provide efficient generation of ions that can perform robust signal processing of radio frequency (RF) through light electromagnetic energy over a range of gas pressures. Applications for such devices are far reaching, including the construction of complete high-frequency plasma-based circuits, and microsystems with superior resistance to radiation and extreme temperature environments. Two and multi-terminal devices consisting of various architectures were developed and optimized under the scope of this program. MPDs were developed in various circuits and substrates to demonstrate the efficacy of different approaches. MPD-based microsystems were demonstrated in DoD applications where electronic systems must survive in extreme environments. The MPD applied research program focused on transferring the fundamental scientific advances funded by PE 0601101E, Project ES-01 to produce complex circuit designs that may be integrated with commercial electronic devices. The MPD program resulted in the design and modeling tools, as well as the fabrication capabilities necessary to commercially manufacture high-performance microscale-plasma-device-based electronic systems for advanced DoD applications. ***FY 2015 Accomplishments:*** - Completed integration of the simulation efforts into the Modeling, Simulation and Design Tool (MSDT) for commercial development of microplasma based electronics. - Completed final testing of microcavity materials for robustness in a high power electromagnetic application in order to demonstrate a Technology Readiness Level (TRL) as needed for technology transition.	2.000	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
- Completed demonstration of plasma-based materials and devices in representative system applications for transition to multiple DoD customers.			
Accomplishments/Planned Programs Subtotals	169.690	174.798	221.911

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

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

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Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	123.292	173.631	182.327	-	182.327	156.089	169.521	184.156	189.156	-	-
AIR-01: *ADVANCED AEROSPACE SYSTEMS*	-	123.292	173.631	182.327	-	182.327	156.089	169.521	184.156	189.156	-	-

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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	129.723	185.043	193.011	-	193.011
Current President's Budget	123.292	173.631	182.327	-	182.327
Total Adjustments	-6.431	-11.412	-10.684	-	-10.684
• Congressional General Reductions	0.000	-1.394			
• Congressional Directed Reductions	0.000	-10.018			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-2.480	0.000			
• SBIR/STTR Transfer	-3.951	0.000			
• TotalOtherAdjustments	-	-	-10.684	-	-10.684

Change Summary Explanation

FY 2015: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2016: Decrease reflects congressional reduction and for Section 8024, FFRDC.
FY 2017: Decrease reflects completion of several Tactically Exploited Reconnaissance Node (TERN) program milestones.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Tactically Exploited Reconnaissance Node (TERN) ***Description:*** The goal of the Tactically Exploited Reconnaissance Node (TERN) program, a joint effort with the Office of Naval Research, is to develop a systems approach for, and perform technical demonstration of, a Medium-Altitude, Long-Endurance	44.558	32.000	12.000

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
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 2015 Accomplishments:*** - Continued technology maturation and completion of preliminary design. - Continued integrated aircraft risk reduction simulation and testing. - Initiated subscale bench testing of propulsion system. - Commenced integrated ship-aircraft simulation activity. - Initiated software in the loop / hardware in the loop design. - Conducted large-scale demonstration of select technology development elements. ***FY 2016 Plans:*** - Complete high fidelity integrated ship-aircraft simulation. - Commence procurement of long-lead demonstrator system components. - Complete detailed design of demonstrator aircraft. - Begin fabrication and testing of demonstrator system hardware. - Initiate software in the loop / hardware in the loop build. - Complete integrated testing of propulsion subsystem. - Initial testing of ship relative navigation system. - Perform 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.			

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Conduct demonstrator system assembly ground checkout.			
Title: Collaborative Operations in Denied Environment (CODE)	19.000	28.543	29.027

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 2015 Accomplishments:
- Performed trade studies and decomposed selected missions.
- Developed collaborative algorithms, autonomous tactics, concepts for communication, and supervisory interface.
- Developed software module specifications compliant with standard based open architecture including OSD unmanned aircraft system control segment and other standards when applicable.
- Evaluated algorithms, tactics, communication and interfaces, in high fidelity faster-than-real time simulation against key performance objectives.

FY 2016 Plans:
- Implement algorithms in first release of flightworthy software (release 1) hosted in mission computer compatible with demonstration platform and objective operational platforms.
- Modify demonstration platform to include mission computer and mesh network capable radio.
- Demonstrate in-flight capabilities of release 1 focused on basic software functionality verification, 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.
- Demonstrate release 1 collaboration algorithms in real time simulation, including low bandwidth sensor fusion and collaborative tasking that maximizes system effectiveness.
- Develop collaborative algorithms, tactics, concepts for communication, and human interface.
- Evaluate algorithms, tactics, communication and interfaces, in non-real time simulation.

FY 2017 Plans:

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Continue development of collaborative algorithms. - Select algorithms for the current leading capabilities: collaborative navigation without GPS, formation flight, simultaneous time of arrival from multiple azimuth 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. - 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. - Validate major software release 2 and 3 in flight with increasing number of real and virtual unmanned airplanes. - Collaborate with operational system owners and other partners to develop early transition opportunities.			
Title: Hypersonic Air-breathing Weapon Concept (HAWC) ***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 2015 Accomplishments:*** - Continued risk reduction testing of subsystem technologies for hypersonic air-breathing missile demonstrator. - Completed technology demonstration system requirements review and began preliminary design of hypersonic air-breathing missile flight demonstration system. - Initiated full-scale freejet propulsion system design and fabrication. - Initiated detailed plans for flight testing of the air-breathing missile demonstration system. ***FY 2016 Plans:*** - Complete preliminary design of hypersonic air-breathing missile flight demonstration system. - Complete full-scale freejet propulsion system testing. - Begin fabrication and testing of thermal protection system materials. - Begin detailed design of the hypersonic air-breathing missile flight demonstration system. - Begin creating test-validated performance databases to anchor demonstration vehicle design.	5.500	13.500	49.500

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Continue detailed plans for flight testing of the air-breathing missile demonstration system. ***FY 2017 Plans:*** - Continue updating test-validated performance databases to anchor demonstration vehicle design. - Complete critical design of hypersonic air-breathing missile flight demonstration system. - Conduct preliminary traceability assessment between the HAWC demonstration system and the HAWC operational system. - Complete 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. - Continue detailed plans for flight testing of the air-breathing missile demonstration system.			
Title: Tactical Boost Glide ***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. ***FY 2015 Accomplishments:*** - Completed TBG Concept of Operations (ConOps), Operational System conceptual design reviews and system capability documentation. - Completed TBG Demonstration System conceptual design and systems requirements reviews. - Completed initial Technology Maturation Plans (TMPs). - Completed initial Risk Management Plans (RMP). - Conducted initial test range and range safety coordination. - Began Phase I aerodynamic and aerothermal concept testing. - Began development of first generation aero databases.	15.100	11.200	22.800

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Completed aerodynamic and aerothermal Government Reference Vehicle (GRV) risk reduction testing. - Completed booster range and energy management study. - Selected booster and launch platforms. ***FY 2016 Plans:*** - Complete operational analysis of the performer TBG operational systems. - Complete operational analysis of evolved Government Reference Vehicle (GRV). - Select TBG demonstration test range. - Complete Phase I aerodynamic and aerothermal concept testing. - Complete first generation aero databases. - Continue risk reduction testing. - Develop initial flight test plan. - Update TMPs and RMPs. - Complete Preliminary Design Reviews (PDR). - Complete initial range safety documentation. ***FY 2017 Plans:*** - Begin TBG concept refinement testing. - Continue risk reduction testing. - Complete second generation aero databases. - Complete 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. - Begin Assembly, Integration, and Test (AI&T). - Continue detailed flight test and range safety planning, coordination, and documentation.			
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/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.	6.360	6.000	3.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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*

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
FY 2015 Accomplishments: - Completed hypersonic propulsion integration and flowpath assessments. - Performed study of rotating detonation engine operation with hydrocarbon fuels, including system design and operational concepts. - Initiated studies of emerging concepts. ***FY 2016 Plans:*** - Perform feasibility experiments of candidate technologies and system concepts. - Conduct trade studies and modeling and simulation for novel technologies. ***FY 2017 Plans:*** - Validate sub-system performance and conduct sub-system risk reduction testing. - Conduct enabling technology and sub-system feasibility experiments.			
Title: Technology for Enriching and Augmenting Manned - Unmanned Systems ***Description:*** The Technology for Enriching and Augmenting Manned - Aircraft (TEAM-US) project seeks 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. The synergy between the mission tailored UAV wingmen and the less survivable, but decision making manned platforms will provide access to contested airspace and enhance force projection. UAV wingmen will reduce air dominance lifecycle costs by dramatically reducing training costs. Legacy manned platforms will train with virtual unmanned teammates saving operations, maintenance, and logistics costs associated with manned wingmen. Unmanned wingmen can be developed for a wide variety of missions including penetrating intelligence, surveillance, and reconnaissance (ISR), electronic attack (EA), and weapons delivery. Mixed operations of manned and unmanned systems in a swarming configuration can be developed to support missions against networked-integrated air defenses and to support operations in highly contested environments. A common core will enable reduced development and integration costs. Finally, leveraging existing platforms for command, control, and battle management recapitalizes existing investments, making these 4th and 5th generation platforms viable participants in future anti-access, area denial scenarios where they may have limited survivability. Balancing in situ battle management with highly capable, mission specific unmanned teammates will offset new threat technologies, enabling more cost effective mission execution, and increasing the survivability of the manned platform team leader. The anticipated transition partners for this effort are the Air Force, Army, and Marine Corps. ***FY 2016 Plans:*** - Perform operational analysis and technology maturity assessments to determine the minimum set of critical platform attributes and technology advances required of an unmanned teammate.	-	9.588	-

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Create a technology development and system attributes demonstration roadmap. - Develop and refine the final unmanned vehicle design and concept.			
Title: Vertical Take-Off and Landing (VTOL) Technology Demonstrator ***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. This program is a continuation of applied research efforts funded in PE 0602702E, Project TT-07. The anticipated transition partners for this effort are the Army, Marine Corps, and Special Operations Forces. ***FY 2016 Plans:*** - Flight test and analyze data from a sub-scale vehicle demonstrator (~340 lb). - Continue preliminary design refinements leading toward detailed design of the demonstrator aircraft and associated subsystems. - Select performer for detailed design, fabrication, and flight test. - Complete preliminary design reviews of configuration and all subsystems. - Refine system design and initiate subsystem critical design reviews. - Initiate software design and flight control law development and simulation. - Develop detailed airworthiness and flight test preparation requirements in support of the full-scale technology demonstrator. - Perform subsystem testing necessary for subsystem design validation and critical design reviews. - Initiate aircraft assembly and manufacturing processes to include tooling design and fabrication. - Procure long-lead items for aircraft fabrication. ***FY 2017 Plans:*** - Complete detailed sub- and system-level validation and verification tests and analyses. - Perform hardware/software-in-the-loop testing. - Complete vehicle management system development and avionics requirements, as well as all elements of ground control and operator/pilot stations. - Complete flight test range selection and finalize flight test plans.	-	58.800	52.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Complete test and evaluation of all elements and sub-systems of the aircraft. - Fabricate and assemble the full, complete aircraft with integrated systems and subsystems.			
Title: Distributed Fires (DFires) ***Description:*** The goal of the Distributed Fires (DFires) program is to create a capability which would allow for precision fires from extended ranges to be rapidly accessed for use. The DFires system would be a stand-alone system that would be transported by trucks, rotorcraft, or boats and delivered to supporting locations on the battlefield. The modular launcher unit would provide the communications link and pass along targeting commands to the onboard stores. The onboard stores would consist of multiple tube launched munitions. Technology areas to be developed include the overall system architecture, the communications requirements and protocols, and specific stores. The anticipated transition partners for this effort are the Army, Marine Corps, and Special Operations Forces. ***FY 2016 Plans:*** - Identify critical anti-access/area-denial theaters of operation. - Conduct trade space analysis and develop overall system architecture. - Assess target value, conduct preliminary design of multiple types of onboard stores. - Explore new technologies which could reduce vehicle size, enhance penetration capability (propulsion and avionics). ***FY 2017 Plans:*** - Conduct Systems Requirements Review (SRR). - Develop system concept of operations (CONOPS) and command and control (C2).	-	6.000	5.000
Title: Advanced Full Range Engine (AFRE) ***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. ***FY 2017 Plans:*** - Begin preliminary design of the TBCC transition demonstration propulsion system, and develop ground test and associated technology development plans. - Design, fabricate, and initiate large scale dual-inlet testing.	-	-	9.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Design, fabricate, and initiate large-scale direct-connect combustor testing, - Initiate procurement of the turbine engine.			
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 developed a vertical take-off and landing (VTOL), modular unmanned air vehicle that can carry a 3,000 lb useful load at a range of 250 nautical miles on a single tank of fuel. ARES enabled distributed operations and access to compact, high altitude landing zones to reduce warfighter exposure to hostile threats and bypass ground obstructions. ARES modular capability allowed 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 was suited for enhanced company operations concepts that would provide the warfighter/team increased situational awareness for operations in an urban environment. The enabling technologies of interest developed under the ARES program included vertical and translational flight, conversion between powered lift and wing borne lift, ducted fan propulsion systems, lightweight materials, tailless configuration, modularity, and advanced over-actuated flight controls for stable transition from vertical to horizontal flight. Additionally, the program explored opportunities for the design, development, and integration of new, key technologies and capabilities. These included adaptable landing gear concepts to enable operations from irregular landing zones and moving launch/recovery platforms, and autonomous take off and landing. The anticipated transition partners for this effort are the Army, Marine Corps, and Special Operations Forces. ***FY 2015 Accomplishments:*** - Completed assembly of drive train components for testing. - Completed assembly of airframe structure for load testing. - Completed proof load testing with flight hardware. - Completed review and revision of rotor control components. - Completed fabrication and assembly of revised rotor control components. - Completed drive train testing with flight components. - Completed development of flight control software to ensure successful flight and ground testing. - Conducted subsystem testing and integration of components into the full scale prototype ARES system. - Completed hardware-in-the-loop and software-in-the-loop testing with fully integrated full scale prototype ARES system. - Conducted ground demonstrations of the prototype vehicle in preparation for flight testing. ***FY 2016 Plans:***	18.000	8.000	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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*

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Conduct flight tests to demonstrate that the vehicle meets program objectives by flying with and without a cargo module to show cargo delivery, and validate flight envelope by expanding speed and altitude performance.			
Title: Persistent Close Air Support (PCAS) ***Description:*** The Persistent Close Air Support (PCAS) program significantly increased close air support (CAS) capabilities by developing a system to allow continuous CAS availability and lethality to the supported ground commander. The enabling technologies were: manned/unmanned attack platforms, next generation graphical user interfaces, data links, digital guidance and control, and advanced munitions. PCAS demonstrated the ability to digitally task a CAS platform from the ground to attack multiple/simultaneous targets. PCAS allowed the Joint Tactical Air Controller (JTAC) the ability to rapidly engage multiple moving targets simultaneously within the area of operation. PCAS's ability to digitally task a CAS platform to attack multiple/simultaneous targets would improve U.S. ground forces operations and speed of attack. The system was designed to reduce collateral damage and potential fratricide to friendly forces. Transition partners include the Air Force, Special Operations Command (SOCOM), and the United States Marine Corps (USMC). ***FY 2015 Accomplishments:*** - Completed flight testing and live fire demonstration of PCAS prototype system on both an A-10C and MV-22. - Transitioned elements of PCAS air and ground systems to USMC and SOCOM. - Prepared and commenced PCAS integration into the MQ-1C. - Conducted testing of the PCAS prototype system on MQ-1C hardware.	14.774	-	-
Accomplishments/Planned Programs Subtotals	123.292	173.631	182.327

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-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*

Product Development ($ in Millions)

				FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total			
Cost Category Item	**Contract Method & Type**	**Performing Activity & Location**	**Prior Years**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Cost To Complete**	**Total Cost**	**Target Value of Contract**
Tactically Exploited Reconnaissance Node (TERN)	C/CPFF	AeroVironment,Inc. : CA	-	13.035	Oct 2014	0.000		0.000		-		0.000	Continuing	Continuing	Continuing
Tactically Exploited Reconnaissance Node (TERN)	C/CPFF	NorthropGrumman : CA	-	17.209	Oct 2014	27.370		9.540		-		9.540	Continuing	Continuing	Continuing
Tactically Exploited Reconnaissance Node (TERN)	C/Various	Various : Various	-	10.202		0.000		0.000		-		0.000	Continuing	Continuing	Continuing
Collaborative Operations in Denied Environment (CODE)	C/Various	Various : Various	-	16.033		4.514		0.000		-		0.000	Continuing	Continuing	Continuing
Collaborative Operations in Denied Environment (CODE)	C/TBD	TBD : TBD	-	0.000		19.960		22.915		-		22.915	Continuing	Continuing	Continuing
Hypersonic Air-breathing Weapon Concept (HAWC)	C/Various	Various : Various	-	2.651		0.000		0.000		-		0.000	Continuing	Continuing	Continuing
Hypersonic Air-breathing Weapon Concept (HAWC)	C/TBD	TBD : TBD	-	0.000		10.585		43.045		-		43.045	Continuing	Continuing	Continuing
Tactical Boost Glide	C/CPFF	LockheedMartin : CA	-	6.159	May 2015	0.000		0.000		-		0.000	Continuing	Continuing	Continuing
Tactical Boost Glide	C/Various	Various : Various	-	2.936		0.000		0.000		-		0.000	Continuing	Continuing	Continuing
Tactical Boost Glide	C/TBD	TBD : TBD	-	0.000		8.692		17.048		-		17.048	Continuing	Continuing	Continuing
Advanced Aerospace System Concepts	C/Various	Various : Various	-	5.788		5.460		2.730		-		2.730	Continuing	Continuing	Continuing
Technology for Enriching and Augmenting Manned - Unmanned Systems	C/TBD	Various : Various	-	0.000		7.920		0.000		-		0.000	0	7.920	0
Vertical Take-Off and Landing (VTOL) Technology Demonstrator	C/TBD	Various : Various	-	0.000		53.008		45.170		-		45.170	Continuing	Continuing	Continuing
Distributed Fires (DFires)	C/TBD	Various : Various	-	0.000		5.995		4.550		-		4.550	Continuing	Continuing	Continuing
Advanced Full Range Engine (AFRE)	C/TBD	Various : Various	-	0.000		0.000		8.190		-		8.190	Continuing	Continuing	Continuing

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency			**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*	

Product Development ($ in Millions)				**FY 2015**		**FY 2016**		**FY 2017 Base**		**FY 2017 OCO**		**FY 2017 Total**			
Cost Category Item	**Contract Method & Type**	**Performing Activity & Location**	**Prior Years**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Cost To Complete**	**Total Cost**	**Target Value of Contract**
Aerial Reconfigurable Embedded System (ARES)	C/CPFF	Lockheed Martin : TX	-	7.277	Mar 2015	0.000		0.000		-		0.000	0	7.277	0
Aerial Reconfigurable Embedded System (ARES)	C/Various	Various : Various	-	8.599		5.550		0.000		-		0.000	0	14.149	0
Persistent Close Air Support (PCAS)	C/Various	Various : Various	-	13.272		0.000		0.000		-		0.000	0	13.272	0
		Subtotal	-	103.161		149.054		153.188		-		153.188	-	-	-

Support ($ in Millions)				**FY 2015**		**FY 2016**		**FY 2017 Base**		**FY 2017 OCO**		**FY 2017 Total**			
Cost Category Item	**Contract Method & Type**	**Performing Activity & Location**	**Prior Years**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Cost To Complete**	**Total Cost**	**Target Value of Contract**
Government Support	MIPR	Various : Various	-	4.936		6.945		7.293		-		7.293	Continuing	Continuing	Continuing
		Subtotal	-	4.936		6.945		7.293		-		7.293	-	-	-

Test and Evaluation ($ in Millions)				**FY 2015**		**FY 2016**		**FY 2017 Base**		**FY 2017 OCO**		**FY 2017 Total**			
Cost Category Item	**Contract Method & Type**	**Performing Activity & Location**	**Prior Years**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Cost To Complete**	**Total Cost**	**Target Value of Contract**
Tactically Exploited Reconnaissance Node (TERN)	C/TBD	Various : Various	-	0.000		1.750		1.380		-		1.380	Continuing	Continuing	Continuing
Collaborative Operations in Denied Environment (CODE)	C/Various	Various : Various	-	1.257		1.500		3.500		-		3.500	Continuing	Continuing	Continuing
Hypersonic Air-breathing Weapon Concept (HAWC)	C/Various	Various : Various	-	2.354		1.700		2.000		-		2.000	Continuing	Continuing	Continuing
Tactical Boost Glide	C/Various	Various : Various	-	4.555		1.500		3.700		-		3.700	Continuing	Continuing	Continuing

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Vertical Take-Off and Landing (VTOL) Technology Demonstrator	C/TBD	Various : Various	-	0.000		0.500		2.150		-		2.150	Continuing	Continuing	Continuing
Aerial Reconfigurable Embedded System (ARES)	C/Various	Various : Various	-	0.504		2.000		0.000		-		0.000	0	2.504	0
Persistent Close Air Support (PCAS)	C/Various	Various : Various	-	0.355		0.000		0.000		-		0.000	0	0.355	0
		Subtotal	-	9.025		8.950		12.730		-		12.730	-	-	-

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	6.170		8.682		9.116		-		9.116	Continuing	Continuing	Continuing
		Subtotal	-	6.170		8.682		9.116		-		9.116	-	-	-

	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	123.292	173.631	182.327	-	182.327	-	-	-

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency			**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*	

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Tactically Exploited Reconnaissance Node (TERN)																												
Risk Reduction Testing		■																										
Large Scale On-Water Demo		■																										
SideArm Full-Scale Test					■																							
Demonstrator System Critical Design Review									■																			
Collaborative Operations in Denied Environment (CODE)																												
System Requirements Review			■																									
Release 1: Single Vehicle Autonomy & Virtual Multi-Vehicle Demonstration						■																						
Preliminary Design Review						■																						
Critical Design Review									■																			
Flight Readiness Review										■																		
Release 2: Collaborative Autonomy with Few Vehicles										■																		
Release 3: Advanced Supervisory Interface and Additional Vehicles												■																
Hypersonic Air-breathing Weapon Concept (HAWC)																												
System Requirements Review		■																										
Full-Scale Freejet Propulsion Fabrication			■																									
Preliminary Design Review					■																							
Begin design of the hypersonic air-breathing missile flight demonstration system							■																					
Critical Design Review										■																		

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Hardware Qualification Testing												■																
Tactical Boost Glide																												
Concept of Operations (ConOps)			■																									
System Requirements Review			■																									
Preliminary Design Review						■																						
Begin Procurement of Hardware for Demo Vehicles											■																	
Critical Design Review												■																
Advanced Aerospace System Concepts																												
Hypersonic Propulsion Integration and Flowpath Assessments		■																										
Initiate Studies of Emerging Concepts		■																										
Trade Studies for Novel Technologies						■																						
Sub-System Risk Reduction Testing										■																		
Sub-System Feasibility Experiments											■																	
Technology for Enriching and Augmenting Manned - Unmanned Systems																												
Refine Final Unmanned Vehicle Design And Concept								■																				
Vertical Take-Off and Landing (VTOL) Technology Demonstrator																												
Preliminary Design Review					■																							
Source Selection for Detailed Design, Fabrication, and Flight Test					■																							
Final Design Review										■																		
Assemble Complete Aircraft											■																	
Distributed Fires (DFires)																												

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*

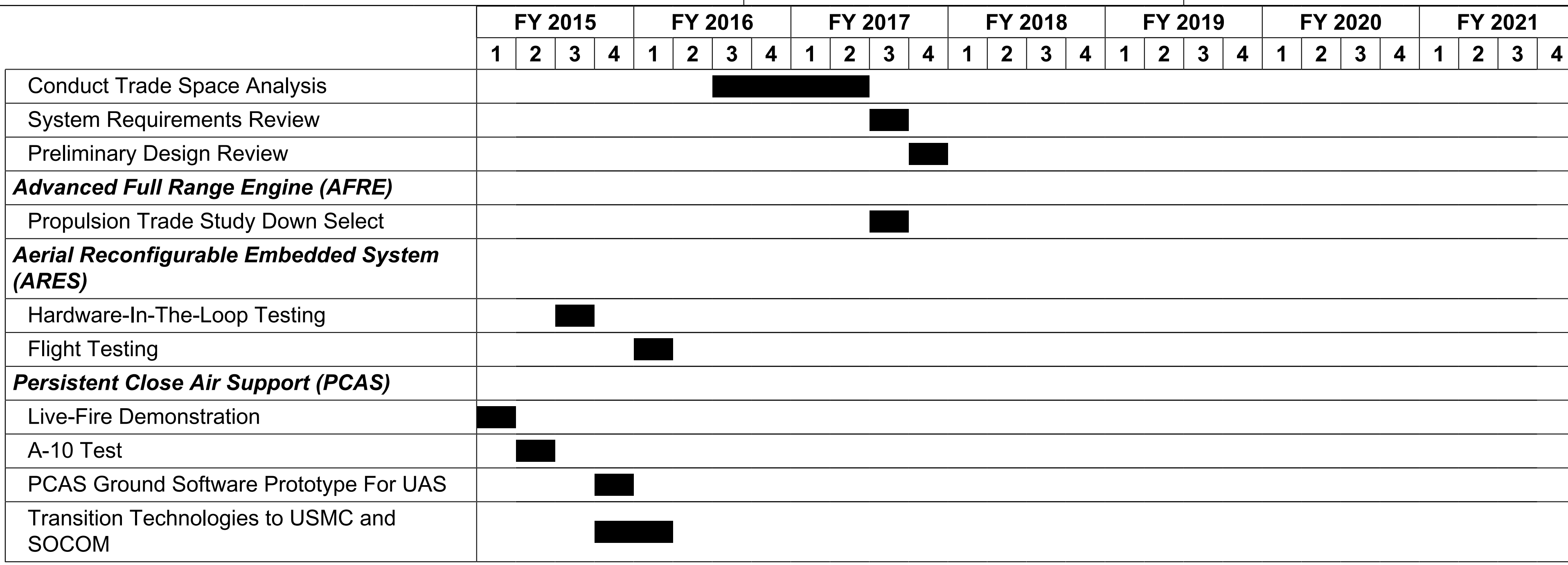

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Tactically Exploited Reconnaissance Node (TERN)				
Risk Reduction Testing	2	2015	2	2015
Large Scale On-Water Demo	2	2015	2	2015
SideArm Full-Scale Test	1	2016	1	2016
Demonstrator System Critical Design Review	1	2017	1	2017
Collaborative Operations in Denied Environment (CODE)				
System Requirements Review	3	2015	3	2015
Release 1: Single Vehicle Autonomy & Virtual Multi-Vehicle Demonstration	2	2016	2	2016
Preliminary Design Review	2	2016	2	2016
Critical Design Review	1	2017	1	2017
Flight Readiness Review	2	2017	2	2017
Release 2: Collaborative Autonomy with Few Vehicles	2	2017	2	2017
Release 3: Advanced Supervisory Interface and Additional Vehicles	4	2017	4	2017
Hypersonic Air-breathing Weapon Concept (HAWC)				
System Requirements Review	2	2015	2	2015
Full-Scale Freejet Propulsion Fabrication	3	2015	3	2015
Preliminary Design Review	1	2016	1	2016
Begin design of the hypersonic air-breathing missile flight demonstration system	3	2016	3	2016
Critical Design Review	2	2017	2	2017
Hardware Qualification Testing	4	2017	4	2017
Tactical Boost Glide				
Concept of Operations (ConOps)	3	2015	3	2015

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
System Requirements Review	3	2015	3	2015
Preliminary Design Review	2	2016	2	2016
Begin Procurement of Hardware for Demo Vehicles	3	2017	3	2017
Critical Design Review	4	2017	4	2017
Advanced Aerospace System Concepts				
Hypersonic Propulsion Integration and Flowpath Assessments	2	2015	2	2015
Initiate Studies of Emerging Concepts	2	2015	2	2015
Trade Studies for Novel Technologies	2	2016	2	2016
Sub-System Risk Reduction Testing	2	2017	2	2017
Sub-System Feasibility Experiments	3	2017	3	2017
Technology for Enriching and Augmenting Manned - Unmanned Systems				
Refine Final Unmanned Vehicle Design And Concept	4	2016	4	2016
Vertical Take-Off and Landing (VTOL) Technology Demonstrator				
Preliminary Design Review	1	2016	1	2016
Source Selection for Detailed Design, Fabrication, and Flight Test	1	2016	1	2016
Final Design Review	2	2017	2	2017
Assemble Complete Aircraft	3	2017	3	2017
Distributed Fires (DFires)				
Conduct Trade Space Analysis	3	2016	2	2017
System Requirements Review	3	2017	3	2017
Preliminary Design Review	4	2017	4	2017
Advanced Full Range Engine (AFRE)				
Propulsion Trade Study Down Select	3	2017	3	2017
Aerial Reconfigurable Embedded System (ARES)				
Hardware-In-The-Loop Testing	3	2015	3	2015

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*	**Project (Number/Name)** AIR-01 / *ADVANCED AEROSPACE SYSTEMS*

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Flight Testing	1	2016	1	2016
Persistent Close Air Support (PCAS)				
Live-Fire Demonstration	1	2015	1	2015
A-10 Test	2	2015	2	2015
PCAS Ground Software Prototype For UAS	4	2015	4	2015
Transition Technologies to USMC and SOCOM	4	2015	1	2016

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	172.504	126.692	175.240	-	175.240	237.435	271.971	252.726	227.726	-	-
SPC-01: *SPACE PROGRAMS AND TECHNOLOGY*	-	172.504	126.692	175.240	-	175.240	237.435	271.971	252.726	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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	179.883	126.692	130.091	-	130.091
Current President's Budget	172.504	126.692	175.240	-	175.240
Total Adjustments	-7.379	0.000	45.149	-	45.149
• 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	-1.900	0.000			
• SBIR/STTR Transfer	-5.479	0.000			
• TotalOtherAdjustments	-	-	45.149	-	45.149

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2016: N/A

FY 2017: Increase reflects expanded requirements in the Experimental Spaceplane One (XS-1), Robotic Servicing of Geostationary Satellites (RSGS), and Radar Net programs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Experimental Spaceplane One (XS-1)	25.000	30.000	50.500
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 2015 Accomplishments:*** - Conducted risk reduction studies for propulsion, thermal protection systems, guidance/avionics, composite materials, propellant tanks and space based communications. - Conducted a mid-phase Conceptual Design and Systems Requirements Review. - Conducted component, wind tunnel, propulsion, cryogenic propellant tank, thermal protection, aero-elasticity testing, ground operations and subsystem testing and verification. - Continued to develop detailed XS-1 designs including mass properties, configuration, aerodynamic, trajectory and thermal protection data. - Conducted a Preliminary Design Review and selected design for technology risk reduction. ***FY 2016 Plans:*** - Develop detailed finite element model structural and thermal analysis for the XS-1 design. - Perform aerodynamic Computational Fluid Dynamics analysis and initiate hypersonic wind tunnel and upper stage separation testing for the XS-1 design to verify aerodynamic models. - Conduct component demonstration and validation ground tests for cryogenic propellant tanks, thermal protection, wing tip aero-elasticity, and additive manufacture of propulsion components and flight demonstrations for take-off and landing operations.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Validate recurring operational costs via discrete event simulations for ground operations and upper stage unit cost analysis and integration costs. - Complete the system and subsystem designs, mass properties and configuration required to support the integrated vehicle design. - Finalize the concept of operation including the maintenance concept, performance, trajectories and design reference missions. - Develop initial plan to accomplish ground operations, facility modifications and flight demonstration. - Coordinate with the Federal Aviation Administration (FAA), DoD ranges and spaceports to accomplish preliminary flight test planning. ***FY 2017 Plans:*** - Complete hypersonic wind tunnel and upper stage separation testing for the XS-1 and incorporate in the flight vehicle design. - Complete structure, thermal protection, and cryogenic tank demonstration and validation testing and incorporate results in the flight vehicle design. - Complete propulsion component demonstration and validation testing. - Complete airframe/propulsion integration for incorporation in the XS-1 flight vehicle design. - Mature the XS-1 concept through critical design review including complete configuration, aero-thermodynamics, six degree of freedom trajectory calculations, mass properties and associated ground systems. - Conduct Critical Design Review to approve XS-1 vehicle design for component acquisition, fabrication, assembly, and integration. - Complete design for all 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 fabrication of flight and ground system hardware.			
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 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	55.000	19.000	8.740

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
a path of risk reduction for modular assembly on orbit. The anticipated transition partners are the Air Force and the commercial spacecraft servicing providers. ***FY 2015 Accomplishments:*** - Completed delta critical design of satlets and of communications system for early LEO experiment. - Completed delta critical design of POD for first GEO flight. - Validated specific servicing mission types that maximize value for commercial and DoD satellite operators. - Began fabrication of robotic hardware and software. ***FY 2016 Plans:*** - Deliver early LEO satlet experiment equipment to launch integrator. - Launch early LEO satlet experiment and conduct experiment operations. - Complete delta critical design of satlets per lessons learned from LEO experiment. - Develop PODs payload hardware for launch. ***FY 2017 Plans:*** - Launch POD and conduct on-orbit testing.			
Title: Robotic Servicing of Geostationary 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 Geostationary 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 cooperation with existing satellite owners, 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. ***FY 2015 Accomplishments:*** - Developed detailed requirements developed from mission description and commercial operator needs. - Completed system requirements review of robotic servicing system including robotic arms and tool docking system. ***FY 2016 Plans:*** - Continue development of servicer robotic payload initiated under the Phoenix program.	4.000	12.000	33.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Conduct studies of suitable satellites to carry the robotic payload. - Establish system requirements for the robotic payload in accordance with primary missions. ***FY 2017 Plans:*** - Select provider for satellite to carry robotic payload. - 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.			
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 initial program is transitioning to Air Force Space Command. The SST Australia effort will provide a further operational demonstration of the SST at the Naval Communication Station Harold E. Holt near Exmouth, Western Australia. Such a location presents a more operationally relevant demonstration, with a richer and more interesting population of SSA targets in geosynchronous orbit. A demonstration in New Mexico will validate telescope performance comparable to the requirement in Australia. In addition, the demonstration will generate data for analysis and fusion efforts, which will be used to further refine and evaluate data processing techniques, such as those developed under the data fusion effort. This program will address technical challenges which may arise from an Australian site, including adaptations to a different telescope environment, and the logistical and communications challenges presented by a site significantly more remote than the current SST location. ***FY 2015 Accomplishments:*** - Continued to refine SST relocation plan jointly with Air Force Space Command (AFSPC) and the Australian Department of Defense partners. - Conducted SST sustainment studies.	9.000	9.000	10.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Developed capability to deliver SST data to Joint Space Operations Center (JSpOC) through Non-Traditional Data Pre-Processor (NDPP). ***FY 2016 Plans:*** - Make improvements to Wide Field Camera (WFC) #2 for improved SST capability. - Install and characterize WFC #2 at White Sands Missile Range (WSMR) site and demonstrate performance improvement. - Support Joint Space Operations Center (JsPOC) data delivery. - Develop plan to transition SST to AFSPC. ***FY 2017 Plans:*** - Complete required documentation for Australian facility. - Support transition to the Air Force.			
Title: Radar Net ***Description:*** The Radar Net program will develop lightweight, low power, wideband capability for radio frequency (RF) communications and remote sensing for a space based platform. The enabling technologies of interest are extremely lightweight and space capable deployable antenna structures. Current deployable antenna options have not been sufficiently developed to be dependable on small payload launches, leaving current capabilities trending to large and more costly launch systems. These launch 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 launches on short timescales with rapid technology refresh capabilities. ***FY 2016 Plans:*** - Develop a detailed system architecture assessment. - Begin cubesat deployable antenna risk reduction. - Commence thermal cycling, power availability, and electrical system analysis. - Conduct pathfinder spacecraft Critical Design Review (CDR). - Conduct prototype Preliminary Design Review (PDR). ***FY 2017 Plans:*** - Conduct prototype CDR. - Conduct pathfinder laboratory and ground tests. - Conduct pathfinder flight qualification. - Launch and conduct pathfinder on-orbit demonstration of multiple deployable antenna technologies. - Demonstrate software defined radio RF capability on appropriate platform. - Perform risk reduction signal processing demonstration.	-	15.000	45.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Integrate results from applications study and pathfinder/risk reduction into prototype design. - Perform early system design reviews.			
Title: Hallmark	-	10.000	28.000
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 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 time-relevant sensor tasking. The program will also improve the ability to protect against threats by use of modeling and simulation tools for both natural and adversary intent determination and course of action development. The program will employ comprehension and visualization techniques to increase commander and operator awareness to transform information to knowledge and effectively communicate and facilitate time-critical decision making. The anticipated transition partner is the Air Force. ***FY 2016 Plans:*** - Initiate space BMC2 interactive simulation environment development. - Conduct demonstration of integrated Government Furnished Equipment (GFE) space BMC2 tools. - Perform demonstration of space BMC2 interactive simulation environment. - Develop a research and development test bed to facilitate the rapid injection of new technologies into the Joint Space Operations Center (JSpOC) and Joint Interagency Coalition Space Operations Center (JICSpOC). - Initiate the cognitive evaluation of operators and decision makers in a demonstration environment to maximize comprehension. - Complete preliminary system design. - Initiate real-time decision tools design development. - Develop sensor data fusion algorithms. - Define course of action data scheme. - 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. ***FY 2017 Plans:*** - Perform existing tool integration. - Develop modeling and simulation infrastructure. - Complete algorithm prototypes. - Complete study of extensible framework. - Commence integration of existing space situational awareness, indications and warning, course of action, and decision support tools.			

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Demonstrate and document integrated tools, algorithms and data schemes.			
Title: Airborne Launch Assist Space Access (ALASA) ***Description:*** The ALASA program seeks to make access to space more affordable by reducing the cost per launch to under one million dollars per flight for 100 lb payloads to low earth orbit. In addition, the program seeks to improve the responsiveness of space access by reducing the interval from call-up to launch to a single day. This enables rapid delivery of spacecraft in response to evolving situations, such as a humanitarian crisis or unexpected conflict, and is accomplished by developing rapid mission planning tools which streamline existing range processes, and automated flight safety systems which reduce reliance on expensive and fragile range infrastructure. These tools enable the program's third goal: to escape the limitations of fixed launch sites by achieving a greater flexibility in the direction and location of launch. Challenges include, but are not limited to: development of a high-energy, low cost monopropellant, development of alternatives to current range processes, and achieving a cost per flight of one million dollars, including range support costs, to deploy satellites on the order of one hundred pounds. The anticipated transition partners are the Air Force and the emerging commercial space launch industry. ***FY 2015 Accomplishments:*** - Conducted propellant production, handling activities, and propellant ignition testing. - Conducted analysis of launch performance metrics and identified opportunities for system design and integration optimization. - Investigated and developed alternative propulsion approach. - Performed system redesign to simplify interfaces and improve payload capacity. ***FY 2016 Plans:*** - Complete propellant characterization to determine operating envelope. - Conduct engine testing to determine constraints and obtain thermal management and performance measurements. - Develop risk assessment and perform modeling and testing of spaced based telemetry, planning tools, and flight termination technology which could decrease impact of launch on commercial air traffic. - Assess alternative propellants and launch systems.	60.000	20.000	-
Title: Optical Aperture Self-Assembly in Space (OASIS) ***Description:*** The Optical Apertures Self-assembling in Space program seeks to demonstrate the feasibility of constructing large optical apertures in orbit from a number of smaller modular components that self-organize in space. The program will demonstrate the technologies needed to assemble a large (>5m) and near-diffraction limited optical aperture from modular components that are launched as separate payloads. The program will include a scalable zero-g demonstration of a functional optical system that maintains the precision and large-scale physical stability required, and utilizes at least one segmented optical surface. This program will address technical challenges of precision mechanical assembly from modular components, multiple object rendezvous and coupling in space, and active surface measurement, compensation and control. Modular construction	2.000	6.000	-

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
in space is intrinsically more challenging than ground-based assembly in that there is not necessarily any measurement and support infrastructure and equipment available, such as interferometer test towers. Therefore, the modular pieces and system design must include self-contained measurement and alignment capabilities to be employed after or during assembly. The OASIS program will demonstrate the feasibility of assembling complex and highly precise structures in space which, in assembled form, are larger than the capacity of any existing or planned space launch vehicle. This capability could enable a number of surveillance and communications instruments in orbit that are not possible today or in the near future under the current paradigm. The anticipated transition partners are the Air Force, Navy and commercial sector. ***FY 2015 Accomplishments:*** - Investigated essential technologies to facilitate self-organizing robotic construction in space. - Developed improved piezopolymer controlled deformable mirrors which can be deployed in a self-assembling orbital optical aperture. - Developed a Photonic Integrated Circuit (PIC) for a proof of concept interferometry demonstration, to enable simultaneous wide angle and zoom capabilities from a single device with no moving parts. - Performed risk reduction activities on strain-deployed, piezo-aligned, lightweight sparse aperture optical concept to support orbital Intelligence, Surveillance, and Reconnaissance (ISR). ***FY 2016 Plans:*** - Continue risk reduction activities on strain-deployed, piezo-aligned, lightweight sparse aperture optical concept to support orbital Intelligence, Surveillance, and Reconnaissance (ISR). - Conduct laboratory demonstration of high resolution capability with light weight optics by leveraging a precision interferometric approach combined with novel image reconstruction algorithm and PIC, which will provide both simultaneous wide angle and zoom capabilities on the same device with no moving parts. - Construct improved piezopolymer controlled deformable mirrors.			
Title: Space Domain Awareness (SDA) ***Description:*** The goal of the Space Domain Awareness (SDA) program is to develop and demonstrate an operational framework and responsive defense application to enhance the availability of vulnerable space-based resources. Current space surveillance sensors cannot detect, track, or determine the future location and threat potential of small advanced technology spacecraft in deep space orbits, where a majority of DoD spacecraft are located. Additionally, servicing missions to geosynchronous earth (GEO) orbits will require exquisite situational awareness, from ultra-high-accuracy debris tracking for mission assurance at GEO orbits to high resolution imaging of GEO spacecraft for service mission planning. SDA will investigate 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,	17.504	5.692	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E I *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
and data processing/fusion to provide automated data synergy. The resulting increase in space domain awareness will enhance overall space safety of flight, and allow space operators to make informed, timely decisions. The SDA program will leverage data fusion and advanced algorithms developed under the Space Surveillance Telescope (SST) program, as well as seek to exploit new ground-breaking technologies across the electromagnetic spectrum and utilize already existing sensor technology in nontraditional or exotic ways, to bring advanced capabilities to the space domain. SDA will demonstrate new approaches to collection of data utilizing a variety of collection modalities, ranging from fusion of observations from non-traditional sources, such as amateur astronomers, to evaluation of sparse aperture imaging techniques. ***FY 2015 Accomplishments:*** - Expanded the SpaceView amateur network to additional nodes including Australia locations. - Incorporated international data sources into SDA database. - Initiated data ingest from the StellarView network of academic astronomy data providers. - Commenced Phase 1 of an un-cued low inclined LEO object detection capability. - Performed database verification on collected data; demonstrated metric and radiometric accuracy. - Studied the application of coherent and quantum detectors to Space Domain Awareness challenges of object detection and imaging. - Initiated Real-Time Space Domain Awareness design development. - Completed development and took delivery of bias estimation, bias aware, bias-aware track generation software, received initial value assessment of data containing biases provided to enhance SDA. ***FY 2016 Plans:*** - Complete an initial capability demonstration of a collaborative network of distributed sensors and users to generate timely, accurate and actionable space indications and warnings. - Integrate 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. - Continue value assessment of data containing biases provided to SDA database. - Expand the portfolio of modalities contributing to SDA to include RADAR data providers. - Integrate SDA database with the US Space Command non-traditional data preprocessor. - Conduct capability demonstration of collaborative network of distributed sensors and users. - Perform and document analysis of algorithm performance.			
Accomplishments/Planned Programs Subtotals	172.504	126.692	175.240

D. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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*

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.

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*	**Project (Number/Name)** SPC-01 / *SPACE PROGRAMS AND TECHNOLOGY*	

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Airborne Launch Assist Space Access (ALASA)	C/CPFF	The Boeing Company : CA	-	53.964	Oct 2014	0.000		0.000		-		0.000	0	53.964	0
Airborne Launch Assist Space Access (ALASA)	C/Various	Various : Various	-	0.000		14.750		0.000		-		0.000	0	14.750	0
Experimental Spaceplane One (XS-1)	C/Various	The Boeing Company : CA	-	5.857	Oct 2014	2.504		0.000		-		0.000	Continuing	Continuing	Continuing
Experimental Spaceplane One (XS-1)	C/CPFF	Northrop Grumman : CA	-	5.427	Dec 2014	2.120		0.000		-		0.000	Continuing	Continuing	Continuing
Experimental Spaceplane One (XS-1)	C/Various	Various : Various	-	11.466		5.376		0.000		-		0.000	Continuing	Continuing	Continuing
Experimental Spaceplane One (XS-1)	C/TBD	TBD : TBD	-	0.000		17.163		44.455		-		44.455	Continuing	Continuing	Continuing
Phoenix	MIPR	Naval Research Laboratory : Various	-	15.766	Nov 2014	15.375		5.900		-		5.900	Continuing	Continuing	Continuing
Phoenix	C/Various	Various : Various	-	34.284		1.915		2.053		-		2.053	Continuing	Continuing	Continuing
Robotic Servicing of Geostationary Satellites (RSGS)	MIPR	Naval Research Laboratory : Various	-	2.000	Nov 2014	4.000		15.000		-		15.000	Continuing	Continuing	Continuing
Robotic Servicing of Geostationary Satellites (RSGS)	C/Various	Various : Various	-	1.640		1.500		5.350		-		5.350	Continuing	Continuing	Continuing
Robotic Servicing of Geostationary Satellites (RSGS)	C/TBD	TBD : TBD	-	0.000		5.420		10.180		-		10.180	Continuing	Continuing	Continuing
Space Surveillance Telescope (SST)	SS/CPFF	Massachusetts Institute of Technology : MA	-	8.190	Nov 2014	8.190		9.100		-		9.100	Continuing	Continuing	Continuing
Radar Net	C/TBD	Various : Various	-	0.000		14.100		36.950		-		36.950	Continuing	Continuing	Continuing
Hallmark	C/TBD	Various : Various	-	0.000		9.100		20.480		-		20.480	Continuing	Continuing	Continuing
Optical Aperture Self-Assembly in Space (OASIS)	C/Various	Various : Various	-	1.820		5.460		0.000		-		0.000	0	7.280	0

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency			**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*	**Project (Number/Name)** SPC-01 / *SPACE PROGRAMS AND TECHNOLOGY*	

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Space Domain Awareness (SDA)	C/Various	Various : Various	-	15.929		5.180		0.000		-		0.000	0	21.109	0
		Subtotal	-	156.343		112.153		149.468		-		149.468	-	-	-

Support ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Government Support	MIPR	Various : Various	-	6.900		5.068		7.010		-		7.010	Continuing	Continuing	Continuing
		Subtotal	-	6.900		5.068		7.010		-		7.010	-	-	-

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Airborne Launch Assist Space Access (ALASA)	C/Various	Various : Various	-	0.636		3.000		0.000		-		0.000	0	3.636	0
Experimental Spaceplane One (XS-1)	C/Various	Various : Various	-	0.000		0.136		1.500		-		1.500	Continuing	Continuing	Continuing
Robotic Servicing of Geostationary Satellites (RSGS)	C/TBD	Various : Various	-	0.000		0.000		0.500		-		0.500	Continuing	Continuing	Continuing
Radar Net	C/TBD	Various : Various	-	0.000		0.000		3.000		-		3.000	Continuing	Continuing	Continuing
Hallmark	C/TBD	Various : Various	-	0.000		0.000		5.000		-		5.000	Continuing	Continuing	Continuing
		Subtotal	-	0.636		3.136		10.000		-		10.000	-	-	-

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*	Project (Number/Name) SPC-01 / *SPACE PROGRAMS AND TECHNOLOGY*

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	8.625		6.335		8.762		-		8.762	Continuing	Continuing	Continuing
		Subtotal	-	8.625		6.335		8.762		-		8.762	-	-	-

	Prior Years	FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	172.504		126.692		175.240		-		175.240	-	-	-

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*	**Project (Number/Name)** SPC-01 / *SPACE PROGRAMS AND TECHNOLOGY*

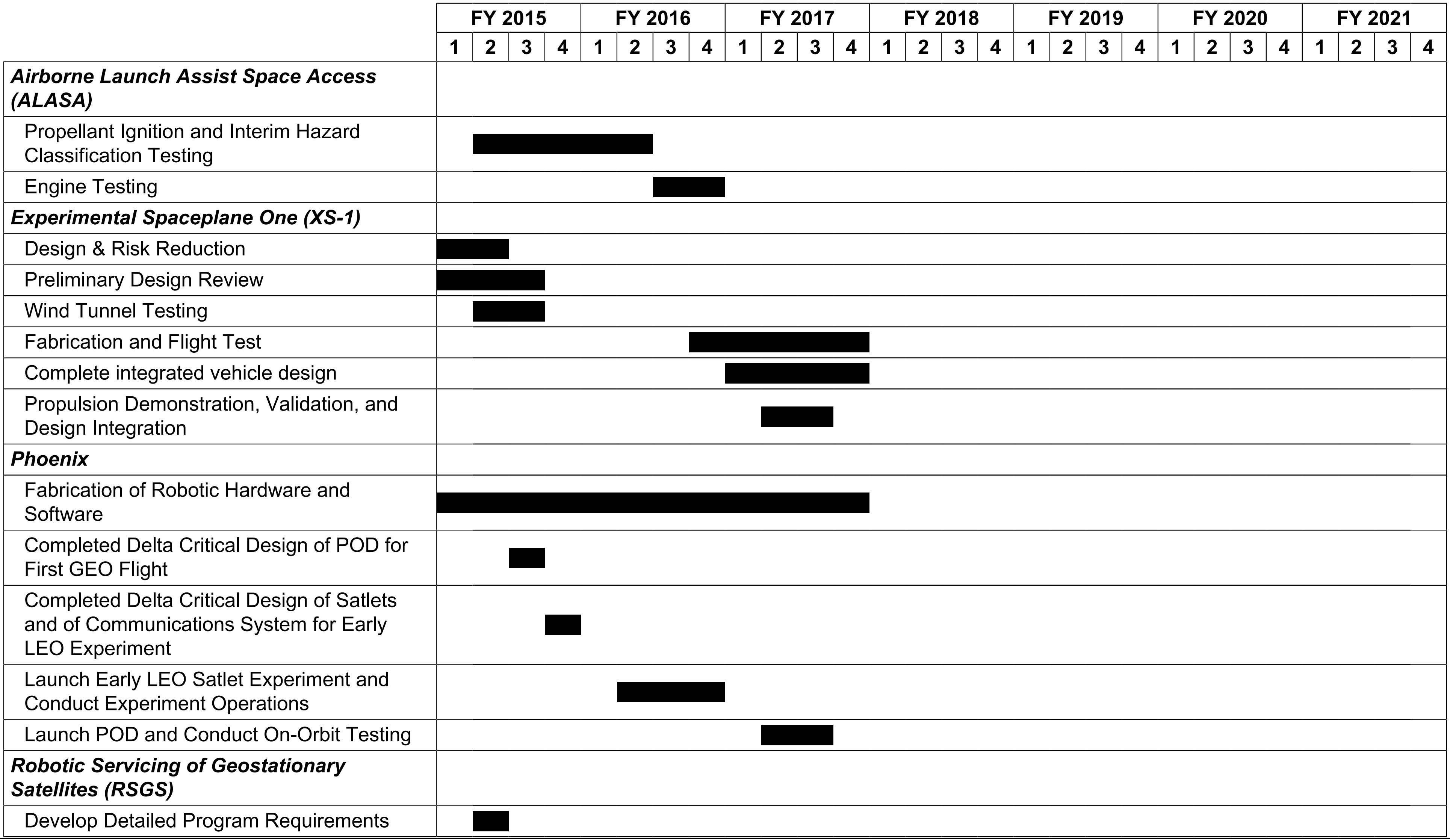

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*	Project (Number/Name) SPC-01 / *SPACE PROGRAMS AND TECHNOLOGY*	

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Continue Development of Servicer Robotic Payload					X	X	X	X																				
Conduct Studies of Suitable Satellites to Carry the Robotic Payload							X	X	X																			
Begin Development of Operator Workstations									X																			
Develop Interface Definition Between Robotic Payload and Satellite										X	X	X																
Space Surveillance Telescope (SST)																												
Refine SST relocation plan with Air Force Space Command (AFSPC) and the Australian Department	X	X	X	X																								
Wide Field Camera #2 Demonstration						X	X																					
Develop Plan to Transition SST to AFSPC								X																				
Finalize Plans to Remove and Recoat Mirrors at Kitt Peak Arizona									X																			
Radar Net																												
Risk Reduction					X	X	X	X	X	X	X																	
System Design							X	X	X	X	X	X																
On-Orbit Risk Reduction Demonstration											X																	
Signal Processing Risk Reduction Demonstration											X																	
System Conceptual Design Review											X																	
Hallmark																												
Initiate space BMC2 interactive simulation environment development							X																					
Complete Architecture Definition							X	X																				

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*	**Project (Number/Name)** SPC-01 / *SPACE PROGRAMS AND TECHNOLOGY*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Demonstrate and document integrated tools, algorithms and data schemes										■																		
Develop modeling and simulation infrastructure										■	■	■																
Optical Aperture Self-Assembly in Space (OASIS)																												
Developed Improved Piezopolymer Controlled Deformable Mirrors		■																										
Conduct final demonstration of Image Quality Refinement						■																						
Space Domain Awareness (SDA)																												
Identify Advanced Collection Technique Need			■																									
Second Data Buy Option			■																									
Advanced Collection Technique First Collect						■																						
Complete initial capability demonstration								■																				

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*	**Project (Number/Name)** SPC-01 / *SPACE PROGRAMS AND TECHNOLOGY*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Airborne Launch Assist Space Access (ALASA)				
Propellant Ignition and Interim Hazard Classification Testing	2	2015	2	2016
Engine Testing	3	2016	4	2016
Experimental Spaceplane One (XS-1)				
Design & Risk Reduction	1	2015	2	2015
Preliminary Design Review	1	2015	3	2015
Wind Tunnel Testing	2	2015	3	2015
Fabrication and Flight Test	4	2016	4	2017
Complete integrated vehicle design	1	2017	4	2017
Propulsion Demonstration, Validation, and Design Integration	2	2017	3	2017
Phoenix				
Fabrication of Robotic Hardware and Software	1	2015	4	2017
Completed Delta Critical Design of POD for First GEO Flight	3	2015	3	2015
Completed Delta Critical Design of Satlets and of Communications System for Early LEO Experiment	4	2015	4	2015
Launch Early LEO Satlet Experiment and Conduct Experiment Operations	2	2016	4	2016
Launch POD and Conduct On-Orbit Testing	2	2017	3	2017
Robotic Servicing of Geostationary Satellites (RSGS)				
Develop Detailed Program Requirements	2	2015	2	2015
Continue Development of Servicer Robotic Payload	1	2016	4	2016
Conduct Studies of Suitable Satellites to Carry the Robotic Payload	3	2016	1	2017
Begin Development of Operator Workstations	1	2017	1	2017

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*	**Project (Number/Name)** SPC-01 / *SPACE PROGRAMS AND TECHNOLOGY*

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Develop Interface Definition Between Robotic Payload and Satellite	2	2017	4	2017
Space Surveillance Telescope (SST)				
Refine SST relocation plan with Air Force Space Command (AFSPC) and the Australian Department	1	2015	4	2015
Wide Field Camera #2 Demonstration	2	2016	3	2016
Develop Plan to Transition SST to AFSPC	4	2016	4	2016
Finalize Plans to Remove and Recoat Mirrors at Kitt Peak Arizona	1	2017	1	2017
Radar Net				
Risk Reduction	1	2016	3	2017
System Design	3	2016	4	2017
On-Orbit Risk Reduction Demonstration	3	2017	3	2017
Signal Processing Risk Reduction Demonstration	3	2017	3	2017
System Conceptual Design Review	3	2017	3	2017
Hallmark				
Initiate space BMC2 interactive simulation environment development	3	2016	3	2016
Complete Architecture Definition	3	2016	4	2016
Demonstrate and document integrated tools, algorithms and data schemes	2	2017	2	2017
Develop modeling and simulation infrastructure	2	2017	4	2017
Optical Aperture Self-Assembly in Space (OASIS)				
Developed Improved Piezopolymer Controlled Deformable Mirrors	2	2015	2	2015
Conduct final demonstration of Image Quality Refinement	2	2016	2	2016
Space Domain Awareness (SDA)				
Identify Advanced Collection Technique Need	3	2015	3	2015
Second Data Buy Option	3	2015	3	2015
Advanced Collection Technique First Collect	2	2016	2	2016
Complete initial capability demonstration	4	2016	4	2016

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Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	81.119	76.021	49.807	-	49.807	74.033	87.960	119.359	165.172	-	-
MT-12: *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	-	13.363	2.200	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	67.756	73.821	49.807	-	49.807	74.033	87.960	119.359	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 program is a broad, cross-disciplinary initiative to merge computation and power generation with sensing and actuation to realize a new technology for both perceiving and controlling weapons systems and battlefield environments. Using fabrication processes and materials similar to those used to make microelectronic devices, MEMS applies the advantages of miniaturization, multiple components and integrated microelectronics to the design and construction of integrated electromechanical and electro-chemical-mechanical systems. The MEMS program addresses issues ranging from the scaling of devices and physical forces to new organization and control strategies for distributed, high-density arrays of sensor and actuator elements. These issues include microscale power and actuation systems as well as microscale components that survive harsh environments. Thermal management technologies will develop heat resistant thermal layers to provide efficient operation for cooling electronic devices.

The Mixed Technology Integration project funds advanced development and demonstrations of selected basic and applied electronics research programs. Examples of activities funded in this project include, but are not limited to: (1) component programs that integrate mixed signal (analog and digital; photonic and electronic) or mixed substrate (Gallium Nitride, Gallium Arsenide, Indium Phosphide, or Silicon Germanium with CMOS) technology that will substantially improve the capability of existing components and/or reduce size, weight and power requirements to a level compatible with future warfighter requirements; (2) development and demonstration of brassboard system applications in such areas as laser weaponry or precision navigation and timing to address mid-term battlefield enhancements; and (3) novel technological combinations (i.e. photonics, magnetics, frequency attenuators) that could yield substantial improvement over current systems.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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*

B. Program Change Summary ($ in Millions)	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	92.246	79.021	87.381	-	87.381
Current President's Budget	81.119	76.021	49.807	-	49.807
Total Adjustments	-11.127	-3.000	-37.574	-	-37.574
• Congressional General Reductions	0.000	-3.000			
• 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	-8.317	0.000			
• SBIR/STTR Transfer	-2.810	0.000			
• TotalOtherAdjustments	-	-	-37.574	-	-37.574

Change Summary Explanation

FY 2015: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2016: Decrease reflects congressional reduction.

FY 2017: Decrease reflects completion of several Endurance, Diverse & Accessible Heterogeneous Integration (DAHI), and FLASH - Scaling Fiber Arrays at Near Perfect Beam Quality program milestones.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
MT-12: *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	-	13.363	2.200	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 funds a broad, cross-disciplinary initiative to merge computation and power generation with sensing and actuation to realize a new technology for both perceiving and controlling weapons systems and battlefield environments. Using fabrication processes and materials similar to those used to make microelectronic devices, MEMS applies the advantages of miniaturization, multiple components and integrated microelectronics to the design and construction of integrated electromechanical and electro-chemical-mechanical systems. The MEMS program addresses issues ranging from the scaling of devices and physical forces to new organization and control strategies for distributed, high-density arrays of sensor and actuator elements. These issues include microscale precision, navigation, and timing systems as well as microscale components that survive harsh environments. These MEMS systems need to operate in a variety of thermal and vibration environments to make them tactically relevant.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Micro-Technology for Positioning, Navigation, and Timing (Micro PN&T) ***Description:*** The Micro-Technology for Positioning, Navigation, and Timing (Micro-PNT) program is developing low-Cost, Size, Weight, and Power (CSWaP) inertial sensors and timing sources for navigation in GPS degraded environments, primarily focusing on the development of miniature solid state and atomic gyroscopes and clocks. Both classes of sensors are currently unsuitable for small platform or dismount soldier applications. Micro Electro-Mechanical Systems (MEMS) sensors have limited performance but excellent CSWaP, while atomic sensors are capable of excellent performance but are limited to laboratory experiments due to complexity and high CSWaP. Micro-PNT is advancing both technology approaches by improving the performance of MEMS inertial sensors and by miniaturizing atomic devices. Ultimately, low-CSWaP inertial sensors and clocks will enable ubiquitous guidance and navigation on all platforms, including guided munitions, unmanned aerial vehicles (micro-UAVs), and mounted and dismounted soldiers. Successful realization of Micro-PNT requires development of new microfabrication processes and novel material systems for fundamentally different sensing modalities, understanding of error sources at the micro-scale, and development of miniature inertial sensors based on atomic physics. Innovative microfabrication techniques under development will allow co-fabrication of dissimilar devices on a single chip, such that clocks, gyroscopes, accelerometers, and calibration stages can be integrated into a small, low power architecture. The program is developing miniature inertial sensors based on atomic interferometry and nuclear magnetic resonance. Ancillary research efforts for this program are funded within PE 0602716E, Project ELT-01.	13.363	2.200	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
FY 2015 Accomplishments: - Fabricated low loss shell resonators for gyroscope applications with ring down time > 100 seconds. - Demonstrated a miniature, self-contained atomic gyroscope with Angle Random Walk (ARW) < 0.05 degrees/sqrt(hr) and bias stability < 0.01 degrees/hr. - Demonstrated self-calibrating MEMS gyroscope with long-term scale factor and bias of < 10 parts per million (ppm) of full scale range. - Demonstrated inertial sensing in both cold-atom and thermal atomic beam atom interferometers. - Demonstrated operation of a MEMS tuning fork gyroscope (TFG) on integrated rotation/calibration stage. ***FY 2016 Plans:*** - Demonstrate a self-contained nuclear magnetic resonance gyroscope with ARW < 5e-4deg/rt(hr) and bias stability <1e-4deg/hr in a 20cc package. - Demonstrate an atom interferometer gyroscope with ARW < 5e-4deg/rt(hr) and bias stability <1e-4deg/hr in <150cc (approximately smartphone sized). - Demonstrate whole angle operation in a 3D microgyroscope. - Demonstrate tactical-grade performance of a single-chip MEMS inertial measurement unit.			
Accomplishments/Planned Programs Subtotals	13.363	2.200	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Micro-Technology for Positioning, Navigation, and Timing (Micro PN&T)	C/Various	Various : Various	-	12.160		2.002		0.000		-		0.000	0	14.162	0
		Subtotal	-	12.160		2.002		0.000		-		0.000	0.000	14.162	0.000

Support ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Government Support	MIPR	Various : Various	-	0.535		0.088		0.000		-		0.000	0	0.623	0
		Subtotal	-	0.535		0.088		0.000		-		0.000	0.000	0.623	0.000

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	0.668		0.110		0.000		-		0.000	0	0.778	0
		Subtotal	-	0.668		0.110		0.000		-		0.000	0.000	0.778	0.000

	Prior Years	FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	13.363		2.200		0.000		-		0.000	0.000	15.563	0.000

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

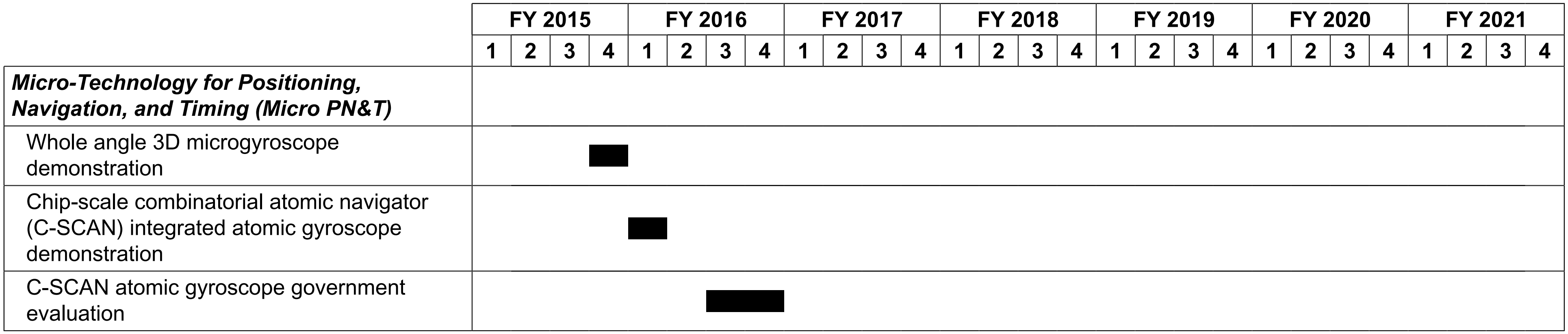

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-12 / *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Micro-Technology for Positioning, Navigation, and Timing (Micro PN&T)				
Whole angle 3D microgyroscope demonstration	4	2015	4	2015
Chip-scale combinatorial atomic navigator (C-SCAN) integrated atomic gyroscope demonstration	1	2016	1	2016
C-SCAN atomic gyroscope government evaluation	3	2016	4	2016

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	67.756	73.821	49.807	-	49.807	74.033	87.960	119.359	165.172	-	-

A. Mission Description and Budget Item Justification

The Mixed Technology Integration project funds advanced development and demonstrations of selected basic and applied electronics research programs. Examples of activities funded in this project include, but are not limited to: (1) component programs that integrate mixed signal (analog and digital; photonic and electronic) or mixed substrate (Gallium Nitride, Gallium Arsenide, Indium Phosphide, or Silicon Germanium with CMOS) technology that will substantially improve the capability of existing components and/or reduce size, weight and power requirements to a level compatible with future warfighter requirements; (2) development and demonstration of brassboard system applications in such areas as laser weaponry or precision navigation and timing to address mid-term battlefield enhancements; and (3) novel technological combinations (i.e., photonics, magnetics, frequency attenuators) that could yield substantial improvement over current systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Endurance	37.669	23.473	15.307
Description: The Endurance program will develop technology for pod- or internally-mounted lasers to protect a variety of airborne platforms from emerging and legacy electro-optical IR guided surface-to-air missiles. The Endurance system will be a completely self-contained laser weapon system brassboard in an open architecture configuration. The focus of the Endurance effort under MT-15 will be to develop and test integrated subsystems, such as a laser subsystem, a command subsystem, a threat missile warning subsystem, a target acquisition and tracking subsystem, a beam control and director subsystem, an energy storage and electrical power delivery subsystem, a thermal management subsystem a mechanical support framework, subsystem interfaces, and the design, integration, and testing of a form/fit/function brassboard laser countermeasure. This program is an early application of technology developed in the Excalibur program and will transition via industry. Applied research for this program is budgeted in PE 0602702E, Project TT-06. ***FY 2015 Accomplishments:*** - Acquired threat devices and/or surrogates in preparation for live fire testing. - Completed the critical design for subsystem integration. - Acquired components for the fabrication of subsystems. ***FY 2016 Plans:*** - Complete fabrication and test subsystems. - Integrate, assemble and bench-test the brassboard system.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Obtain necessary range approvals for live-fire testing. ***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. - Develop a preliminary engineering design for a flight-prototype of a pod-mounted laser weapon system.			
Title: Diverse & Accessible Heterogeneous Integration (DAHI) ***Description:*** The scaling of silicon (Si) transistors to ever smaller dimensions has led to dramatic gains in processor performance over the past fifty years. In parallel, integrated circuit (IC) designers for radio frequency (RF) circuits have leveraged the different material properties of compound semiconductor (CS) technologies such as indium phosphide (InP), gallium arsenide (GaAs), gallium nitride (GaN) and silicon-germanium (SiGe) to enable devices that operate at frequencies and powers difficult or impossible to achieve in Silicon. Historically, a designer would have to decide between the high density of Si circuits or the high performance of CS materials. Prior DARPA efforts have demonstrated the ability to achieve near-ideal "mix-and-match" capability for DoD circuit designers with limited demonstrations of the heterogeneous integration of silicon and InP technologies that far exceeded what can be accomplished with one technology alone. Specifically, the Compound Semiconductor Materials On Silicon (COSMOS) program enabled transistors of InP to be freely mixed with silicon complementary metal-oxide semiconductor (CMOS) circuits to obtain the benefits of both technologies (very high speed and very high circuit complexity/density, respectively). The Diverse & Accessible Heterogeneous Integration (DAHI) effort will take this capability to the next level, ultimately offering the seamless co-integration of a variety of semiconductor devices (for example, GaN, InP, GaAs, antimonide based Compound Semiconductors), microelectromechanical (MEMS) sensors and actuators, photonic devices (e.g., lasers, photo-detectors) and thermal management structures. This capability will revolutionize our ability to build true "systems on a chip" (SoCs) and allow dramatic size, weight and volume reductions while enabling higher performance such as power, bandwidth or dynamic range in our electronic systems for electronic warfare, communications and radar. This program has applied research efforts funded in PE 0602716E, Project ELT-01. The Advanced Technology Development part of this program will leverage these complementary efforts to focus on the establishment of an accessible, manufacturable technology for device-level heterogeneous integration of a wide array of materials and devices (including, for example, multiple electronics and MEMS technologies) with complex silicon-enabled (e.g. CMOS) architectures on a common silicon substrate platform. This part of the program is expected to culminate in accessible foundry processes of DAHI technology and demonstrations of advanced microsystems with innovative architectures and designs that leverage heterogeneous integration. By the end of the program, this effort seeks to establish a technologically mature, sustainable DAHI foundry service to be made available (with appropriate computer-aided design support) to a wide variety of DoD laboratory, Federally Funded Research and Development Center (FFRDC), academic and industrial designers.	15.496	15.335	6.000

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
FY 2015 Accomplishments: - Developed 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 (silicon (Si) CMOS, InP heterojunction bipolar transistors (HBTs), GaN high-electron-mobility transistors (HEMTs), and high-Q passive devices). - Demonstrated heterogeneously integrated yield test circuits using three device technologies (Si CMOS, InP HBTs, and GaN HEMTs) with measured reliability data. Tracked fabrication process issues and risks and systematically mitigated or eliminated them, resulting in yield structures which meet program metrics. - Demonstrated capability for supporting multi-project wafer runs using the heterogeneous foundry service under development. - Demonstrated a multi-project wafer run including eight external design teams using the DAHI process. Facilitated multi-project wafer foundry through development and support of process design kit and thermal simulation tools. ***FY 2016 Plans:*** - Complete 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 (Si CMOS, InP HBTs, GaN HEMTs, and high-Q passive devices). - Complete demonstration of capability for supporting multi-project wafer runs using the heterogeneous foundry service under development. ***FY 2017 Plans:*** - Complete 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 (Si CMOS, InP HBTs, GaN HEMTs, and high-Q passive devices). Finalize refinements of yield and reliability, and coordinate with self-sustaining foundry activity to ensure successful transition of heterogeneous integration technology. - Complete demonstration of capability for supporting multi-project wafer runs using the heterogeneous foundry service under development. Finalize the development of seamless process design kits and integrated design flows to facilitate the use of the foundry service by external users.			
Title: FLASH - Scaling Fiber Arrays at Near Perfect Beam Quality ***Description:*** The goal of the FLASH program is to demonstrate a transportable, ultra-low size, weight, and power (SWaP), packaged laser system by coherently combining the outputs of an array of ultra-lightweight, flight-worthy high-power fiber lasers. The packaged FLASH laser system will project a >30-kW-class beam with near perfect beam quality and very high electrical-to-optical efficiency. The SWaP will be consistent with weight and volume densities needed to support the integration of laser weapons on a broad range of military platforms, including 4th and 5th generation aircraft and UAVs. To accomplish these objectives, FLASH will: (1) greatly reduce the overall size and weight of packaged coherently-combinable high-power fiber laser amplifiers while greatly simplifying the demands they make on support systems such as cabling, cooling lines and	12.591	15.813	12.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
support structures while increasing their efficiency and resistance to shock, vibration and acoustics; and (2) fabricate an array of these ultralight fiber-laser amplifiers and integrate them with advanced battery power, thermal management and coherent-beam combination sub-systems into a transportable, fully packaged, ultra-low SWaP laser system. ***FY 2015 Accomplishments:*** - Developed and tested a packaged, flight-worthy, coherently-combinable, fiber laser amplifier with an output power, beam-quality, size and weight consistent with system integration on tactical aircraft. - Developed a preliminary design for a >30 kW transportable, packaged laser system including fiber lasers, thermal management, power systems, and beam combination. - Demonstrated, on a lab bench, the coherent combination of over 100 low power fiber lasers into a single beam as a proof-of-concept for the high power system. - Demonstrated, on a lab bench, the coherent combination of 42 output beams of kW-class fiber lasers into a single beam with high efficiency and near-perfect beam quality. ***FY 2016 Plans:*** - Develop a critical design for a >30 kW transportable, packaged laser system. - Fabricate and/or procure parts and hardware for the >30 kW transportable, packaged laser system. - Assemble and test key subsystems for the >30 kW transportable, packaged laser system. - Begin the integration of key subsystems for a >30 kW transportable, packaged laser system. ***FY 2017 Plans:*** - Complete integration of the >30 kW transportable, packaged laser system. - Test and demonstrate the >30 kW transportable, packaged laser system.			
Title: Common Heterogeneous integration & IP reuse Strategies (CHIPS)* ***Description:*** *Formerly Fast and Big Mixed-Signal Designs (FAB) Developing capabilities to intermix and tightly integrate silicon processes which are currently supported at different scaling nodes and by different vendors is critical to increasing the capabilities of high-performance military microelectronics. For example, Silicon-Germanium (SiGe) Bipolar Complementary Metal-oxide Semiconductor (BiCMOS) processes allow CMOS logic to be integrated with radio frequency (RF) heterojunction bipolar transistors (HBTs), which enables mixed-signal circuits having RF analog capabilities tightly coupled to digital processing. However, the SiGe process flow was developed to integrate to a single CMOS technology node and significant design and engineering effort is required to retarget the flow for a new node. Thus, BiCMOS processes tend to lag behind commercial CMOS by several generations. CHIPS will investigate the potential for a truly process-agnostic integration technology, i.e., one that is inclusive of any current or future circuit fabrication technology such as	-	4.200	5.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
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 2015	FY 2016	FY 2017
Gallium Arsenide (GaAs), Gallium Nitride (GaN) and SiGe with a standardized interconnect topology. Such a technology platform will enable the design of individual circuit Intellectual Property (IP) blocks, such as low-noise amplifiers and analog-to-digital converters, with a goal of re-use of the IP across applications. Re-use will allow the DoD to amortize the upfront design cost of these blocks over several designs instead of leveling the burden on a single program. Furthermore, the IP can be designed in the fabrication process best suited for the performance goals and evolve more quickly than larger, more expensive single chip systems-on-a-chip. Through standardization of the interface, CHIPS will enable the DoD to leverage the advancements driven by the global semiconductor market rather than relying on a single on-shore foundry provider or on proprietary circuit designs owned by a handful of traditional prime performers. In the Advanced Technology Development part of this program, focus will be placed on the development of rapid development and insertion of microsystems utilizing III-V semiconductors and other microelectronic technologies with advanced Si CMOS. This program has Applied Research efforts funded in PE 0602716E, Project ELT-01. ***FY 2016 Plans:*** - Investigate analog intellectual property (IP) reuse techniques for efficient, rapid fabrication of high-performance RF/microwave circuits. - Develop standardized, high-bandwidth interfaces for chiplet-to-chip interconnection. - Initiate circuit demonstration using intellectual property reuse techniques. ***FY 2017 Plans:*** - Conduct system demonstrations using standardized, high-bandwidth interfaces for chiplet-to-chip interconnection of heterogeneous IP. - Initiate circuit demonstrations of chip-to-chip interconnects for heterogeneous IP RF electronic chip stacks.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM) ***Description:*** The DoD relies on GPS for ubiquitous and accurate positioning, navigation, and timing (PNT). With the increased prevalence of intentional GPS jamming, spoofing, and other GPS-denial threats, GPS access is increasingly unavailable in contested theaters and alternative sources of PNT are required. In particular, guided munitions navigation is the most immediate and among the most demanding of GPS-denial challenges, due to the necessity of operating in highly contested theaters and the stringent requirements for minimization of cost, size, weight, and power consumption (CSWaP). The Precise Robust Inertial Guidance for Munitions (PRIGM) program will develop low-CSWaP inertial sensor technology for GPS-free munitions navigation. PRIGM comprises two focus areas: 1) Development of a Navigation-Grade Inertial Measurement Unit (NGIMU) that transitions state-of-the-art MEMS to DoD platforms by 2020; and 2) Research and development of Advanced Inertial MEMS Sensors (AIMS) to achieve gun-hard, high-bandwidth, high dynamic range navigation requirements with the objective of complete autonomy in 2030. PRIGM will advance state-of-the-art MEMS gyros from TRL-3 devices to a TRL-6 transition platform (complete IMU) that	-	13.000	10.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
enables Service Labs to perform TRL-7 field demonstrations. PRIGM will exploit recent advances in heterogeneous integration of photonics and CMOS and advanced MEMS technology to realize novel inertial sensors for application in extreme dynamic environments and beyond navigation-grade performance. At present, DoD suffers a trade-space dichotomy between low-CSWaP tactical-grade IMUs, based on MEMS inertial sensors, and relatively high-CSWaP navigation-grade IMUs, based on ring-laser or interferometric fiber-optic gyroscopes (RLG/iFOG). RLG/iFOG is the technology of choice for high-value platforms. However, for the vast majority of platforms (munitions, dismounts, UAVs), CSWaP necessitates the use of lower-performance, MEMS-based IMUs. Under the micro-PNT program, DARPA has developed MEMS gyroscopes with performance rivaling that of navigation-grade interferometric fiber optic gyros (IFOGs), thus exposing a new tradespace for low-CSWaP navigation grade IMUs. The ultimate goal of the program is to develop a complete MEMS-based navigation-grade IMU with an identical mechanical/electronic interface to existing DoD-standard tactical-grade MEMS IMUs, thereby providing a drop-in replacement for existing DoD systems and rapid transition through early insertion demonstrations. 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 Plans:*** - Initiate efforts to demonstrate MEMS inertial sensors that meet all NGIMU performance and environmental requirements. - Design, fabricate, and characterize MEMS gyroscopes meeting stability and repeatability specifications consistent with navigation-grade performance. - Design, fabricate, and characterize MEMS accelerometers meeting stability and repeatability specifications consistent with navigation-grade performance. ***FY 2017 Plans:*** - 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. - Commence development of MEMS-based, navigation-grade, integrated IMU meeting program-defined SWaP and performance metrics, excluding environmental requirements and shock survival.			
Title: Direct SAMpling Digital ReceivER (DISARMER) ***Description:*** The goal of the Direct SAMpling Digital ReceivER (DISARMER) program is to produce a hybrid photonic-electronic analog-to-digital converter (ADC) capable of coherently sampling the entire X-band (8-12 GigaHertz (GHz)). Conventional	2.000	2.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
electronic wideband receivers are limited in dynamic range by both the electronic mixer and the back-end digitizers. By employing an ultra-stable optical clock, the DISARMER program will allow for mixer-less digitization and thereby improve the dynamic range 100x over the state of the art. Such a wide-bandwidth, high-fidelity receiver will have applications in electronic warfare and signals intelligence systems with the potential to drastically reduce the cost, size and weight of these systems. The DISARMER program will design, fabricate, and test a hybrid photonic-electronic ADC packaged in a standard form factor. This involves the integration of electronic and photonic circuits, packaging of a mode-locked laser with ultralow jitter, and delivering a field programmable gate array with the necessary firmware to process the sampled data. This program has applied research efforts funded in PE 0602716E, Project ELT-01. ***FY 2015 Accomplishments:*** - Designed, assembled, and tested the prototype track-and-hold chip with 8 channels and optimized optical response to minimize the parasitic capacitance of the circuit. - Demonstrated direct sampling of a 4 GHz-wide bandwidth signal at 7 effective bits of fidelity. ***FY 2016 Plans:*** - Demonstrate direct sampling of a 4 GHz-wide bandwidth signal at 10 effective bits of fidelity. - Test system performance across both baseband and the entire X-band (8-12 GHz).			
Accomplishments/Planned Programs Subtotals	67.756	73.821	49.807

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-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*	

Product Development ($ in Millions)

				FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total			
Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	Cost	Award Date	Cost	Award Date	Cost	Award Date	Cost	Award Date	Cost	Cost To Complete	Total Cost	Target Value of Contract
Endurance	C/CPFF	NorthropGrumman : CA	-	18.920	Sep 2015	10.742		7.063		-		7.063	Continuing	Continuing	Continuing
Endurance	C/Various	Various : Various	-	12.932		8.534		3.652		-		3.652	Continuing	Continuing	Continuing
Diverse & Accessible Heterogeneous Integration (DAHI)	C/CPFF	NorthropGrumman : CA	-	11.004	May 2015	5.910		0.000		-		0.000	Continuing	Continuing	Continuing
Diverse & Accessible Heterogeneous Integration (DAHI)	C/Various	Various : Various	-	3.097		8.045		5.185		-		5.185	Continuing	Continuing	Continuing
FLASH - Scaling Fiber Arrays at Near Perfect Beam Quality	C/Various	Various : Various	-	11.568		14.280		11.375		-		11.375	Continuing	Continuing	Continuing
Direct SAMpling Digital ReceivER (DISARMER)	C/Various	Various : Various	-	1.820		1.820		0.000		-		0.000	Continuing	Continuing	Continuing
Common Heterogeneous integration & IP reuse Strategies (CHIPS)	C/TBD	Various : Various	-	0.000		3.672		4.755		-		4.755	Continuing	Continuing	Continuing
Precise Robust Inertial Guidance for Munitions (PRIGM)	C/TBD	Various : Various	-	0.000		11.830		9.555		-		9.555	Continuing	Continuing	Continuing
		Subtotal	-	59.341		64.833		41.585		-		41.585	-	-	-

Support ($ in Millions)

				FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total			
Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	Cost	Award Date	Cost	Award Date	Cost	Award Date	Cost	Award Date	Cost	Cost To Complete	Total Cost	Target Value of Contract
Government Support	MIPR	Various : Various	-	2.655		3.083		2.242		-		2.242	Continuing	Continuing	Continuing
		Subtotal	-	2.655		3.083		2.242		-		2.242	-	-	-

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Endurance Testing	C/Various	Various : Various	-	2.427		2.084		3.214		-		3.214	Continuing	Continuing	Continuing
		Subtotal	-	2.427		2.084		3.214		-		3.214	-	-	-

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	3.333		3.821		2.766		-		2.766	Continuing	Continuing	Continuing
		Subtotal	-	3.333		3.821		2.766		-		2.766	-	-	-

	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	67.756	73.821	49.807	-	49.807	-	-	-

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Endurance																												
System Integration Critical Design Review				■																								
Fabricate and Test Subsystem							■																					
Integrated System Initial Laboratory Test										■																		
Live Fire Range Test												■																
Diverse & Accessible Heterogeneous Integration (DAHI)																												
HI Complex Circuit Design		■	■																									
HI Complex Circuit Fabrication and Test				■	■	■	■																					
HI Complex Circuit Iteration Design					■	■	■																					
HI Complex Circuit Iteration Fabrication and Test							■	■	■	■																		
FLASH - Scaling Fiber Arrays at Near Perfect Beam Quality																												
Compact Laser Preliminary Design Review				■																								
Compact Laser Critical Design Review						■																						
Compact Laser Amplifier Prototype								■																				
Integrated Laser System Initial Test										■																		
Integrated Laser System Final Demonstration												■																
Direct SAMpling Digital ReceivER (DISARMER)																												
Full System Demonstration			■																									
Integration of Sub-Modules			■	■	■	■	■																					
Final System Demonstration								■																				
Common Heterogeneous integration & IP reuse Strategies (CHIPS)																												

Exhibit R-4, **RDT&E Schedule Profile:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

	FY 2015				**FY 2016**				**FY 2017**				**FY 2018**				**FY 2019**				**FY 2020**				**FY 2021**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Program Initiation					■																							
Phase 1 Contract Awards							■																					
Standard Interface Design Review										■																		
Heterogeneous Chip Modular Design Review												■																
Precise Robust Inertial Guidance for Munitions (PRIGM)																												
Program Initiation					■																							
Government Evaluation of Inertial Sensors							■																					
Phase 1 to 2 Transition Decision											■																	

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Endurance				
System Integration Critical Design Review	4	2015	4	2015
Fabricate and Test Subsystem	3	2016	3	2016
Integrated System Initial Laboratory Test	2	2017	2	2017
Live Fire Range Test	4	2017	4	2017
Diverse & Accessible Heterogeneous Integration (DAHI)				
HI Complex Circuit Design	2	2015	3	2015
HI Complex Circuit Fabrication and Test	4	2015	3	2016
HI Complex Circuit Iteration Design	1	2016	3	2016
HI Complex Circuit Iteration Fabrication and Test	3	2016	2	2017
FLASH - Scaling Fiber Arrays at Near Perfect Beam Quality				
Compact Laser Preliminary Design Review	4	2015	4	2015
Compact Laser Critical Design Review	2	2016	2	2016
Compact Laser Amplifier Prototype	4	2016	4	2016
Integrated Laser System Initial Test	2	2017	2	2017
Integrated Laser System Final Demonstration	4	2017	4	2017
Direct SAMpling Digital ReceivER (DISARMER)				
Full System Demonstration	3	2015	3	2015
Integration of Sub-Modules	3	2015	3	2016
Final System Demonstration	4	2016	4	2016
Common Heterogeneous integration & IP reuse Strategies (CHIPS)				
Program Initiation	1	2016	1	2016

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Phase 1 Contract Awards	3	2016	3	2016
Standard Interface Design Review	2	2017	2	2017
Heterogeneous Chip Modular Design Review	4	2017	4	2017
Precise Robust Inertial Guidance for Munitions (PRIGM)				
Program Initiation	1	2016	1	2016
Government Evaluation of Inertial Sensors	3	2016	3	2016
Phase 1 to 2 Transition Decision	3	2017	3	2017

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	229.945	201.335	155.081	-	155.081	185.554	174.104	163.853	164.183	-	-
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	124.497	102.415	93.781	-	93.781	129.204	123.909	142.233	152.183	-	-
CCC-04: *SECURE INFORMATION AND NETWORK SYSTEMS*	-	2.450	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	102.998	98.920	61.300	-	61.300	56.350	50.195	21.620	12.000	-	-

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 goal of the Information Integration Systems project is to develop and demonstrate technologies that will provide effective communications to U.S. forces. 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. 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 a very high-threat environments.
- Novel Radio Frequency and Spectral Sensing (RF/SS) - supports efficient spectrum management in congested environments and detection of electromagnetic threats.

The Secure Information and Network Systems project developed and demonstrated computer and network technologies and systems suitable for use in military networks, U.S. government enterprise networks, critical infrastructure, and embedded computing systems. The project developed, integrated, and tested technologies for re-using software components.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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*

B. Program Change Summary ($ in Millions)	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	239.265	201.335	122.646	-	122.646
Current President's Budget	229.945	201.335	155.081	-	155.081
Total Adjustments	-9.320	0.000	32.435	-	32.435
• 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	-2.033	0.000			
• SBIR/STTR Transfer	-7.287	0.000			
• TotalOtherAdjustments	-	-	32.435	-	32.435

Change Summary Explanation

FY 2015: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2016: N/A
FY 2017: Increase reflects expansion of Project CCC-06 programs.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	124.497	102.415	93.781	-	93.781	129.204	123.909	142.233	152.183	-	-

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 2015	FY 2016	FY 2017
Title: 100 Gb/s RF Backbone	13.200	21.750	15.638

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 2015 Accomplishments:
- Built and evaluated modulators capable of generating higher-order waveforms and demodulators capable of digitizing the higher-order waveforms.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Evaluated higher-order modulation approaches at mmW frequencies in field demonstrations up to tactically relevant distances. - Evaluated hardware and software capable of spatially multiplexing and de-multiplexing multiple mmW signals. - Evaluated mmW spatial multiplexing approaches to distances at or beyond the Rayleigh Range. - Commenced design and development of an integrated prototype system that includes both higher-order modulation and spatial multiplexing. ***FY 2016 Plans:*** - Continue to reduce the size, weight, and power of the system components to metrics consistent with high altitude, long endurance aerial platforms. - Conduct laboratory tests of merged higher-order modulation and spatial multiplexing technologies. - Initiate prototype performance evaluation planning for mountain-to-ground tests at a Government test range. - Conduct initial prototype testing using multiple system configurations to characterize initial system performance. ***FY 2017 Plans:*** - 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. - Transition the 100 Gb/s RF Backbone system to multiple Services.			
Title: Spectrum Efficiency and Access ***Description:*** Current Presidential Initiatives, FCC Broadband Task Force, and Congressional legislation are working to transition large swaths of spectrum (up to 500 MHz) from Federal (DoD is the primary contributor) to civilian use for broadband telecommunications. The DoD will need more highly integrated and networked data/sensor capacity over the next decades and will therefore need new technology that requires less spectrum to operate. The objective of the Spectrum Efficiency and Access program is to investigate improvements in spectral reuse, such as spectrum sharing of sensor/radar bands. The program will leverage technical trends in cooperative sharing to exploit radar anti-jam and interference mitigation technologies that could enable spectrum sharing by allowing overlay of communications within the same spectral footprint. The approach will include exploring real-time control data links between radars and communications systems, and developing the advanced waveforms and components to enable radars and communication networks to operate in close proximity. The ultimate goal is to turn the DoD spectrum loss into a net gain of up to hundreds of MHz in capacity. Technology from this program will be made available to the DoD. ***FY 2015 Accomplishments:*** - Modeled and assessed multiple mechanisms for spatial and temporal spectrum sharing between radars and communications networks.	17.462	16.990	15.752

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Developed and assessed a baseline set of strategies to defend military systems against threats created by sharing spectrum information between military radars and commercial communications systems. - Developed concepts for a control system to manage mechanisms for spectrum sharing between radars and communication systems. - Demonstrated technologies for signal separation between radar and communications systems operating at the same time, place, and frequency. - Developed concepts and approaches for a joint system design between military radar and military communications systems operating in a shared spectrum allocation that improves overall performance in electronic countermeasure operating environments. ***FY 2016 Plans:*** - Model and assess methods for automatically mitigating interfering transmissions caused by malfunctioning or misconfigured communications devices. - Develop and assess updated strategies to defend military systems against threats created by sharing spectrum information between military radars and commercial communications systems. - Develop baseline version of control system to manage spectrum sharing mechanisms. - Conduct laboratory demonstrations of spectrum sharing among conforming radar and military and commercial communications systems that incorporates multiple sharing mechanisms. - Perform initial vulnerability assessment of the spectrum sharing control system and sharing mechanisms through simulated attacks. - Model and assess 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 control system to manage spectrum sharing mechanisms. - Modify military and commercial radio and communications systems to support spectrum sharing mechanisms. - Conduct field demonstrations of spectrum sharing among conforming radar and communications systems that incorporates multiple sharing mechanisms. - Reassess vulnerability of the spectrum sharing control system and sharing mechanisms through simulated attacks. - Develop methods for automatically mitigating interfering transmissions caused by malfunctioning or misconfigured communications devices and assess through simulations.			
Title: Advanced RF Mapping ***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	17.705	17.125	11.866

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017

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. It 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 2015 Accomplishments:
- Carried out field experiments that demonstrated use of currently deployed tactical radios as sensors within a heterogeneous RF mapping network.
- Developed a software layer that simplifies addition of new capabilities to the heterogeneous RF mapping network after it has been fielded.
- Demonstrated improved battlefield spectrum planning and spectrum management operations through feedback of spectrum utilization information from RF sensors.
- Developed a command and control system for optimizing use of devices as RF sensors in a changing operational environment.
- Developed and demonstrated geo-location capability of RF emitters using the heterogeneous RF mapping network.

FY 2016 Plans:
- Conduct RF Mapping tactical demonstrations.
- Develop 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.
- Develop a baseline user interface for presenting RF mapping information to tactical units.
- Develop software for interconnecting the RF mapping capability with other tactical Electronic Warfare (EW) systems enabling cueing and results sharing.
- Develop interface control documentation (ICD) that permits vendors to independently integrate third party RF devices and applications for use as additional RF Mapping sensors.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop 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. - 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.			
Title: Communication in Contested Environments (C2E)	18.000	18.000	9.263
Description: Building upon the technologies explored and developed under the Computational Leverage Against Surveillance Systems (CLASS) program budgeted in this PE/Project, the Communication in Contested Environments (C2E) program will seek to address communications problems anticipated in networked airborne systems in the mid-21st century. Expected growth in sensor systems, unmanned systems, and internetworked weapons systems will strain the size of networks that our current communications technology can support in the contested environment. As adversary capabilities advance, the DoD will need new techniques to quickly and efficiently accommodate better networking and improved communications capabilities, specifically communications systems with higher capacity, lower latency, greater jamming resistance, and reduced detectability. As part of Advanced Networking technologies efforts, the C2E program addresses these needs with a three-pronged approach: first, to develop heterogeneous networking capabilities and advanced communication technology for airborne systems. Low Probability of Detection (LPD), Anti-Jam (AJ), low latency, and high capacity communication protocols will be developed. Second, to create a government controlled and maintained reference architecture for communications systems that draws from commercial communication architectures. The defense contractor community can build specific communications systems based upon this reference architecture. Finally, C2E will create a government controlled development environment to allow rapid refresh of communications technology and allow third party native application and waveform developers to contribute their own communications technologies. Technologies from this program are planned to transition to the Services. ***FY 2015 Accomplishments:*** - Designed, built, and tested the RF Transceiver and Digital waveform processor circuit card assemblies leveraging technology from the DARPA CLASS program. - Designed, built, and tested a communications reference hardware system to support L-band and microwave communications. - Decomposed waveform implementations into re-usable processing elements and compiled representative waveforms for the reference hardware, including initial design for an application-specific integrated circuit (ASIC). - Tested infrastructure networking code on the reference system and evaluated pervasive networking performance.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Deployed the first instantiation of the software development environment for streamlined creation of C2E compliant waveforms and applications. ***FY 2016 Plans:*** - Complete development of advanced network processing functions for implementation in an ASIC. - Finalize and integrate LPD/AJ capabilities. - Release updated version of the combined software architecture, development environment and tool set, verification environment, and repository. - Demonstrate Heterogeneous Networking LPD/AJ features, and implement an initial prototype of the C2E reference design on a small form factor radio. - Finalize development of the C2E waveforms and demonstrate performance through laboratory testing. - Demonstrate airborne tactical network waveform interoperability on the C2E reference architecture. - Enhance the software development environment to improve functionality and ease of use. ***FY 2017 Plans:*** - Finalize verification testing and system integration of the C2E ASIC. - Complete development of the C2E ASIC operating system, hardware drivers, and encoder drivers. - Complete development and testing of the small form factor radio with integrated C2E ASIC. - Demonstrate legacy waveform interoperability on the small form factor radio.			
Title: Communications Module - Millimeter-wave (COMMO-MMW) ***Description:*** The Communications Module - Millimeter-wave (COMMO-MMW) program will develop a compact, scalable, millimeter wave (mm-wave) active electronically scanned array (AESA) module to enable high-performance communications links. The module will focus on low cost connectivity of weapons platforms and systems. The cost will be reduced through exploitation of mass manufacturing techniques at the chip scale and a reduction in size of the system which will aid in retrofitting into existing platforms. The COMMO-MMW module will operate in the high frequency portion of the electromagnetic spectrum to take advantage of reduced competition for bandwidth compared to the increasingly congested bands at lower frequencies. By leveraging mass manufacturing processes to reduce module cost, and new advances in compound semiconductors to enhance system performance, the COMMO-MMW program will realize affordable mm-wave communications that can be made ubiquitous across the domains of modern warfare. Additionally, mm-wave operation offers the potential for extremely high data rate communications links that are intrinsically jam resistant and low probability of detection due to narrow beamwidths and atmospheric propagation characteristics at these frequencies. The lack of commercial component technology in the mm-wave band will further increase the military advantage gained by this capability. This program will develop the critical compound semiconductor devices and circuits for high performance, high power efficiency mm-wave front end electronics, and will apply 3-D and/or heterogeneous integration approaches to build a compact, scalable, mm-wave AESA module. COMMO-MMW not only will	-	7.000	22.762

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
revolutionize Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) capability but also make it possible and affordable to retrofit existing military systems and extend high performance communications link capability to smaller platforms. Technologies developed under this program will transition to the Services and will provide the capability of "fiber-like" connectivity rates in infrastructure free environments. ***FY 2016 Plans:*** - Analyze and design a compact, scalable, mm-wave AESA module supporting a communication demonstration system for long-range power-constrained missions. - Define specifications for the critical components of a 4 x 4 element AESA. - Develop and demonstrate integration approaches for a compact, scalable, mm-wave AESA module with high output power and high power-added efficiency. ***FY 2017 Plans:*** - Develop and demonstrate mm-wave devices and circuits to be integrated for transmitter and receiver array demonstration. - Develop a system integration and test plan for the 4x4 element AESA system. - Develop and demonstrate a low-bandwidth communications link based on the COMMO-MMW 4x4 element arrays.			
Title: Dynamic Network Adaptation for Mission Optimization (DyNAMO)* ***Description:*** *Formerly Self-Optimizing Networks Wireless networks have evolved into complex systems having many configurable parameters/features, including link data rates, power settings, inter-network gateways, and security associations. The optimal settings for these features vary greatly depending on the mission for which the network is deployed and the environment in which it is operating. Currently, the majority of these features are optimized off-line for specific scenarios and assumptions and are pre-set before use in a mission. There is no capability for the settings to adapt if the actual mission or environment differs from the original assumptions used to configure the network. The problem is exacerbated in scenarios in which intelligent adversaries can affect the topology and operation of the network unpredictably and on short timescales. Furthermore, future operations will include multiple, different radios interconnected on the same platform, and those existing networks lack a common standard for interoperability. The Dynamic Network Adaptation for Mission Optimization (DyNAMO) program will develop software that addresses the incompatibilities preventing information sharing across independent airborne networks and develop new approaches to configure and control networks and networks of networks for operation in dynamic and contested environments. The program will address optimization within legacy and future military networks, interactions between networks, and availability of necessary network services to support mission success. Technologies developed under this program will transition to the Services. ***FY 2016 Plans:***	-	5.050	18.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Commence development of candidate near-real-time optimization algorithms to improve network reliability and efficiency when affected by advanced threats. - Propose and analyze candidate inter-network coordination and decentralized network services for operation in the presence of a peer adversary. - Commence development of mission-based network architecture control and information delivery mechanisms. - Conduct testing of individual technology developments in an emulation environment. ***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 system-level emulation test of system with internetwork coordination and mission-based control. - Conduct hardware-in-the-loop test of system with internetwork coordination and mission-based control.			
Title: Wireless Network Defense ***Description:*** A highly networked and enabled force increases efficiency, effectiveness, and safety by making relevant information available when it is needed and at the appropriate location (person/platform/system). Accomplishing this depends on providing reliable wireless communications to all U.S. forces, platforms, and devices in all phases of conflict. 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 of the complex system, and mitigate the corresponding effects. Technologies developed under this program will transition to the Services. ***FY 2015 Accomplishments:*** - Completed integration of candidate algorithms and protocols for protecting networks from, and detecting and reacting to, misinformation attacks in laboratory-based prototype systems. - Created emulation testbed for evaluating performance of network under various network attacks. - Tested resilience of prototype capabilities in a laboratory environment. - Refined protection mechanisms based on test findings and began development of systems for field demonstrations.	18.880	16.500	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Quantified the performance impact of network misconfiguration in simulations of networks in contested environments. ***FY 2016 Plans:*** - Increase severity of attacks on prototype system and continue to test resilience in laboratory environment. - Complete integration of candidate algorithms and protocols to prepare for field experiments. - Test resilience of prototype capabilities against advanced attacks in a field environment. - Refine protection mechanisms based on test findings and begin development of systems for transition to military tactical radios. - Integrate with military tactical radios and quantify the performance impact through experiments.			
Title: Computational Leverage Against Surveillance Systems (CLASS) ***Description:*** Commercial Test and Measurement equipment has advanced greatly with the emergence of sophisticated cellular and wireless local area network technology and can be used to intercept, analyze, and exploit our military communications signals. The Computational Leverage Against Surveillance Systems (CLASS) program worked to expand Low Probability of Detection/Anti-Jam (LPD)/(AJ) technologies, sought new ways to protect our signals from exploitation by increasingly sophisticated adversaries in ways that can be maintained as commercial technology advances. Three different techniques were developed: 1) Waveform Complexity uses advanced communications waveforms that are difficult to recover without knowledge and understanding of the signals itself; 2) Spatial Diversity uses distributed communications devices and the communication environment to disguise and dynamically vary the apparent location of the signal; and 3) Interference Exploitation makes use of the clutter in the signal environment to make it difficult for an adversary to isolate a particular signal. The program's objective was to make modular communications technology that was inexpensive to incorporate in existing and emerging radio systems (< $100 incremental cost) but pushed adversaries to need more than 1,000x our processing power - supercomputer-level processing power. Another track of the program extended the CLASS technology to provide LPD communications. These techniques drastically reduced the detectability of communications signals beyond current capabilities. Scalable performance allowed LPD techniques to better trade information rate for communications capacity. Technologies from this program will transition to the Services. ***FY 2015 Accomplishments:*** - Developed concepts for integrating CLASS technologies with aircraft antennas and communications equipment. - Measured CLASS modem performance processing power, power consumption, and radio waveform interoperability. - Integrated CLASS modular technology with host processor. - Demonstrated CLASS communication capability with and without interference against Army threat intercept surrogates. - Measured CLASS modem transmit power reduction as number of cooperative transmitters was increased from 1 transmitter to multiple transmitters. - Conducted field tests of integrated CLASS system. - Analyzed field test data and compared achieved performance to program metrics.	24.600	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Transitioned CLASS technology to Army and Navy customers.			
Title: Mobile Hotspots ***Description:*** Communications requirements have grown exponentially due to the proliferation of high-data rate sensors (full motion video), Unmanned Aerial Vehicles (UAVs), and the emergence of the Soldier/Marine as both an operator and a sensor within military networks. However, limited spectrum availability results in a large disparity between capacity requirement and availability. Supporting the development of Advanced Networks technologies, Mobile Hotspots developed an airborne high capacity data distribution network to interconnect groups of tactical users in a manner conceptually similar to the commercial tiered approach of interconnecting cell towers and wireless hotspots. Mobile Hotspots exploited advances in millimeter-wave technology and airborne networking to develop a self-organizing, 1 Gb/s mobile tactical airborne network formed from highly-directional communications links to interconnect mounted and dismounted warfighters, dispersed tactical operations centers, and intelligence, surveillance and reconnaissance (ISR) assets. Low size, weight, and power (SWaP) designs were integrated with commercial and military communications equipment and mounted on tactical UAVs and ground vehicles to provide network access to mobile users via infrastructure-less hotspots compatible with existing radios. The Mobile Hotspots program will transition to the Army and Marine Corps Expeditionary Forces. ***FY 2015 Accomplishments:*** - Evaluated initial capabilities of the Mobile Hotspot prototype network and millimeter-wave tactical airborne network in an initial ground-based field experiment. - Identified and implemented system and subsystem improvements in preparation for final field experimentation and flight test. - Conducted ground testing of integrated air and ground vehicle systems to validate system operation and performance. - Conducted flight tests to evaluate system performance in various air-to-air, air-to-ground, and multi-node networking configurations.	14.650	-	-
Accomplishments/Planned Programs Subtotals	124.497	102.415	93.781

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-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
100 Gb/s RF Backbone (100G)	C/Various	Various : Various	-	3.680		5.900		7.700		-		7.700	Continuing	Continuing	Continuing
100 Gb/s RF Backbone (100G)	C/CPFF	NORTHROP GRUMMAN SYSTEMS CORPORATION : CA	-	8.771	Sep 2015	12.607		4.350		-		4.350	Continuing	Continuing	Continuing
Spectrum Efficiency and Access	C/Various	Various : Various	-	10.950		8.942		10.413		-		10.413	Continuing	Continuing	Continuing
Spectrum Efficiency and Access	C/CPFF	LEIDOS,INC. : VA	-	5.353	Oct 2015	6.832		2.820		-		2.820	Continuing	Continuing	Continuing
Advanced RF Mapping	C/Various	Various : Various	-	6.648		6.926		7.273		-		7.273	Continuing	Continuing	Continuing
Advanced RF Mapping	C/CPFF	LOCKHEED MARTIN CORPORATION : VA	-	8.311	Sep 2015	7.918		3.750		-		3.750	Continuing	Continuing	Continuing
Communication in Contested Environments (C2E)	C/Various	Various : Various	-	13.797		13.876		8.051		-		8.051	Continuing	Continuing	Continuing
Communications Module - Millimeter-wave (COMMO-MMW)	C/Various	Various : Various	-	0.000		6.500		13.987		-		13.987	Continuing	Continuing	Continuing
Dynamic Network Adaptation for Mission Optimization (DyNAMO)	C/Various	Various : Various	-	0.000		4.500		16.900		-		16.900	Continuing	Continuing	Continuing
Wireless Network Defense	C/Various	Various : Various	-	14.145		12.193		0.000		-		0.000	0	26.338	0
Computational Leverage Against Surveillance Systems (CLASS)	C/Various	Various : Various	-	18.514		0.000		0.000		-		0.000	0	18.514	0
Mobile Hotspots	C/Various	Various : Various	-	5.674		0.000		0.000		-		0.000	0	5.674	0
Mobile Hotspots	C/CPFF	L-3 COMMUNICATIONS	-	6.200	Nov 2014	0.000		0.000		-		0.000	0	6.200	0

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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*

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
		CORPORATION : UT													
		Subtotal	-	102.043		86.194		75.244		-		75.244	-	-	-

Support ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Government Support	MIPR	Various : Various	-	4.980		4.097		3.751		-		3.751	Continuing	Continuing	Continuing
		Subtotal	-	4.980		4.097		3.751		-		3.751	-	-	-

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
100 Gb/s RF Backbone (100G)	C/Various	Various : Various	-	0.069		0.523		3.150		-		3.150	Continuing	Continuing	Continuing
Advanced RF Mapping	C/Various	Various : Various	-	0.525		1.220		0.329		-		0.329	Continuing	Continuing	Continuing
Communication in Contested Environments (C2E)	SS/FFP	Various : Various	-	3.836		3.810		0.382		-		0.382	Continuing	Continuing	Continuing
Communications Module - Millimeter-wave (COMMO-MMW)	C/Various	Various : Various	-	0.000		0.000		5.636		-		5.636	Continuing	Continuing	Continuing
Dynamic Network Adaptation for Mission Optimization (DyNAMO)	C/Various	Various : Various	-	0.000		0.000		0.600		-		0.600	Continuing	Continuing	Continuing
Wireless Network Defense	C/Various	Various : Various	-	2.385		1.450		0.000		-		0.000	0	3.835	0
Computational Leverage Against Surveillance Systems (CLASS)	SS/FFP	Various : Various	-	2.878		0.000		0.000		-		0.000	0	2.878	0

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Mobile Hotspots	C/Various	Various : Various	-	1.556		0.000		0.000		-		0.000	0	1.556	0
		Subtotal	-	11.249		7.003		10.097		-		10.097	-	-	-

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	6.225		5.121		4.689		-		4.689	Continuing	Continuing	Continuing
		Subtotal	-	6.225		5.121		4.689		-		4.689	-	-	-

	Prior Years	FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	124.497		102.415		93.781		-		93.781	-	-	-

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

	FY 2015				**FY 2016**				**FY 2017**				**FY 2018**				**FY 2019**				**FY 2020**				**FY 2021**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
100 Gb/s RF Backbone																												
System design and technology development / technology demonstrations		■																										
Prototype testing						■																						
Field testing										■																		
System flight testing												■																
Spectrum Efficiency and Access																												
Demonstration of signal separation technologies	■																											
Lab demonstration of spectrum sharing							■																					
Limited field demonstrations											■																	
Advanced RF Mapping																												
Field experiments and demonstration	■																											
Demonstration of geo-location capability				■																								
Tactical demonstration							■																					
Software development & testing						■	■	■																				
Field demonstrations										■																		
Communication in Contested Environments (C2E)																												
Transceiver and waveform processor circuit card testing		■																										
Infrastructure networking code testing			■																									
Software development environment deployment				■																								
Software architecture development & release						■																						
Integrated system demo											■																	

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Networking demonstration									■																			
Communications Module- Millimeter-wave (COMMO-MMW)																												
Program initiation					■	■	■	■																				
COMMO-MMW Sub-Array Integration contract awards											■																	
Dynamic Network Adaptation for Mission Optimization (DyNAMO)																												
Program initiation					■	■	■	■																				
Mission based network technology testing							■	■																				
System-level emulation test									■	■																		
Mission-based network architecture integration										■	■	■																
Hardware-in-the-loop system testing											■	■																
Wireless Network Defense																												
Algorithm and protocol integration				■																								
Algorithm and protocol integration testing						■	■	■																				
Computational Leverage Against Surveillance Systems (CLASS)																												
Software/hardware testing			■																									
Field tests of integrated system				■																								
Mobile Hotspots																												
Build, integrate, and test / ground tests			■																									
Flight test and demonstration				■																								

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
100 Gb/s RF Backbone				
System design and technology development / technology demonstrations	2	2015	2	2015
Prototype testing	2	2016	2	2016
Field testing	2	2017	2	2017
System flight testing	4	2017	4	2017
Spectrum Efficiency and Access				
Demonstration of signal separation technologies	1	2015	1	2015
Lab demonstration of spectrum sharing	3	2016	3	2016
Limited field demonstrations	3	2017	3	2017
Advanced RF Mapping				
Field experiments and demonstration	1	2015	1	2015
Demonstration of geo-location capability	4	2015	4	2015
Tactical demonstration	3	2016	3	2016
Software development & testing	2	2016	4	2016
Field demonstrations	2	2017	2	2017
Communication in Contested Environments (C2E)				
Transceiver and waveform processor circuit card testing	2	2015	2	2015
Infrastructure networking code testing	3	2015	3	2015
Software development environment deployment	4	2015	4	2015
Software architecture development & release	2	2016	2	2016
Integrated system demo	3	2017	3	2017
Networking demonstration	1	2017	1	2017

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

Events by Sub Project	Start Quarter	Start Year	End Quarter	End Year
Communications Module- Millimeter-wave (COMMO-MMW)				
Program initiation	1	2016	4	2016
COMMO-MMW Sub-Array Integration contract awards	3	2017	3	2017
Dynamic Network Adaptation for Mission Optimization (DyNAMO)				
Program initiation	1	2016	4	2016
Mission based network technology testing	3	2016	4	2016
System-level emulation test	1	2017	2	2017
Mission-based network architecture integration	2	2017	4	2017
Hardware-in-the-loop system testing	3	2017	4	2017
Wireless Network Defense				
Algorithm and protocol integration	4	2015	4	2015
Algorithm and protocol integration testing	2	2016	4	2016
Computational Leverage Against Surveillance Systems (CLASS)				
Software/hardware testing	3	2015	3	2015
Field tests of integrated system	4	2015	4	2015
Mobile Hotspots				
Build, integrate, and test / ground tests	3	2015	3	2015
Flight test and demonstration	4	2015	4	2015

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-04 / *SECURE INFORMATION AND NETWORK SYSTEMS*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
CCC-04: *SECURE INFORMATION AND NETWORK SYSTEMS*	-	2.450	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

Computer and networking technologies have advanced rapidly with profound effect on the DoD and the nation. The Secure Information and Network Systems project developed and demonstrated computer and network technologies and systems suitable for use in military networks, U.S. government enterprise networks, critical infrastructure, and embedded computing systems. The project developed, integrated, and tested technologies for re-using software components.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Rapid Software Development using Binary Components (RAPID) ***Description:*** The Rapid Software Development using Binary Components (RAPID) program developed a system to identify and extract software components for reuse in new applications. The DoD has critical applications that must be ported to future operating systems. In many cases, the application source code is no longer available requiring these applications to continue to run on unsecure and outdated operating systems, impacting operations. A companion applied research effort was budgeted in PE 0602303E, Project IT-03. RAPID capabilities are transitioning to the Services. ***FY 2015 Accomplishments:*** - Transitioned system outputs based on results from technology evaluation exercises. - Deployed prototype systems at transition partner sites to support initial operations.	2.450	-	-
Accomplishments/Planned Programs Subtotals	2.450	-	-

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-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-04 / *SECURE INFORMATION AND NETWORK SYSTEMS*

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Rapid Software Development using Binary Components (RAPID)	C/Various	Various : Various	-	2.229		0.000		0.000		-		0.000	0	2.229	0
		Subtotal	-	2.229		0.000		0.000		-		0.000	0.000	2.229	0.000

Support ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Rapid Software Development using Binary Components (RAPID)	MIPR	Various : Various	-	0.098		0.000		0.000		-		0.000	0	0.098	0
		Subtotal	-	0.098		0.000		0.000		-		0.000	0.000	0.098	0.000

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Rapid Software Development using Binary Components (RAPID)	C/Various	Various : Various	-	0.123		0.000		0.000		-		0.000	0	0.123	0
		Subtotal	-	0.123		0.000		0.000		-		0.000	0.000	0.123	0.000

	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	2.450	0.000	0.000	-	0.000	0.000	2.450	0.000

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-04 / *SECURE INFORMATION AND NETWORK SYSTEMS*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Rapid Software Development using Binary Components (RAPID)																												
Participated in Cyber Flag Activities	■																											
Installed Pilot Systems at Transition Partner Site		■																										
Participated in Cyber Guard Activities			■																									
Participated in Red Flag Activities				■																								

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-04 / *SECURE INFORMATION AND NETWORK SYSTEMS*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Rapid Software Development using Binary Components (RAPID)				
Participated in Cyber Flag Activities	1	2015	1	2015
Installed Pilot Systems at Transition Partner Site	2	2015	2	2015
Participated in Cyber Guard Activities	3	2015	3	2015
Participated in Red Flag Activities	4	2015	4	2015

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	102.998	98.920	61.300	-	61.300	56.350	50.195	21.620	12.000	-	-

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 2015	FY 2016	FY 2017
Title: Classified DARPA Program ***Description:*** This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2015 Accomplishments:*** Details will be provided under separate cover. ***FY 2016 Plans:*** Details will be provided under separate cover. ***FY 2017 Plans:*** Details will be provided under separate cover.	102.998	98.920	61.300
Accomplishments/Planned Programs Subtotals	102.998	98.920	61.300

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Details will be provided under separate cover.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	350.323	425.861	428.894	-	428.894	410.027	392.905	368.717	337.668	-	-
NET-01: *JOINT WARFARE SYSTEMS*	-	45.784	66.219	72.916	-	72.916	111.556	144.765	160.416	202.367	-	-
NET-02: *MARITIME SYSTEMS*	-	72.980	119.401	138.303	-	138.303	126.321	162.344	145.301	135.301	-	-
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	231.559	240.241	217.675	-	217.675	172.150	85.796	63.000	0.000	-	-

A. Mission Description and Budget Item Justification

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

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

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

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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*

B. Program Change Summary ($ in Millions)	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	360.426	452.861	470.582	-	470.582
Current President's Budget	350.323	425.861	428.894	-	428.894
Total Adjustments	-10.103	-27.000	-41.688	-	-41.688
• Congressional General Reductions	0.000	-7.000			
• Congressional Directed Reductions	0.000	-20.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.875	0.000			
• SBIR/STTR Transfer	-10.978	0.000			
• TotalOtherAdjustments	-	-	-41.688	-	-41.688

Change Summary Explanation

FY 2015: Decrease reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2016: Decrease reflects congressional reduction.
FY 2017: Decrease reflects the completion of several classified programs.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
NET-01: *JOINT WARFARE SYSTEMS*	-	45.784	66.219	72.916	-	72.916	111.556	144.765	160.416	202.367	-	-

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 2015	FY 2016	FY 2017
Title: System of Systems Integration Technology and Experimentation (SoSite)	17.411	36.109	35.681
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 2015 Accomplishments:*** - Developed reference objective system of systems architecture.			

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017

- Commenced development of architecture demonstration plan, including range and platform options.
- Implemented M&S capabilities for architecture design analysis and validation.
- Commenced the development of system of systems synthesis and integration tools and protocols.
- Commenced development of engineering tools to validate system of systems architecture designs.
- Commenced development of formal verification techniques to validate integration of constituent systems into a system of systems.
- Investigated technologies to facilitate multi-level open architecture security.
- Explored alternative systems architectures, designs, tools, and protocols for the maritime environment.

FY 2016 Plans:
- Complete development of architecture demonstration plan, including range and platform options.
- Develop a System Integration Laboratory (SIL) to support Government verification and validation of system of systems architectures.
- Complete the development of system of systems synthesis and integration tools and protocols.
- Complete prototype architecture designs to implement the system of systems concept.
- Initiate experimentation in constructive and virtual environments to validate system of systems approach.
- Assess in SIL the capability of new engineering tools to validate system of systems architecture designs.
- Assess in SIL the capability of new formal verification techniques to validate integration of constituent systems into a system of systems.
- Verify prototype of system of systems architectures in M&S environments.
- Develop technologies to facilitate multi-level open architecture security M&S.
- Identify the most promising alternative systems architectures, designs, tools, and protocols for the maritime environment.

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 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.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Conduct experiments of system of systems architectures 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.			
Title: Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE) ***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 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. 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 2015 Accomplishments:*** - Developed initial concept of operations (CONOPS) for a distributed, communications-challenged set of capabilities to support an integrated strike, ISR, and spectrum management planning and assessment working in place of a fixed Air Operations Center (AOC). - Developed initial system architecture and software framework for distributed strike, ISR, and spectrum management to include planning, assessment, and dynamic replanning. - Developed initial models and simulation capability for testing, analysis, and validation of a set of distributed planning and assessment components working in a communications-challenged environment. - Commenced development of algorithms and prototypes for distributed planning and assessment components. ***FY 2016 Plans:*** - Complete initial development of algorithms and prototypes for distributed planning and assessment components. - Develop models and simulation capability for testing, analysis, and validation of a distributed system operating in a communications-challenged environment. - Implement the framework designs into a software prototype. - Test and evaluate candidate software frameworks and components. - Commence development of decision support tools for operational planning. ***FY 2017 Plans:***	11.300	18.236	25.948

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Develop experiments to highlight the planning and assessment capabilities in both a distributed and communications-challenged environment. - Continue integration efforts with the prototype framework. - 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.			
Title: Retrodirective Arrays for Coherent Transmission (ReACT) ***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 to demonstrate the capability to combine distributed mobile transmitters to provide high-power spatially resolved EW beams at frequencies utilized by adversary communications and radars. ReACT will achieve this capability by synchronizing multiple distributed transmitters to form a much larger effective array than a single platform could support. The key technical challenge is to synchronize distributed and moving transmitters while compensating for platform motion and vibration. Further, the ReACT system must sense the target's emissions and then optimally configure the ReACT transmitters to focus on the area to be jammed, as well as the minimum power required to sufficiently jam the target. 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 EW beamforming. The ReACT technology is planned to transition to the Air Force and Navy. ***FY 2016 Plans:*** - Complete development of algorithms and hardware for coherent beamforming under mobile environments. - Design vibration compensation circuit for feedback control. - Design algorithms that target an adversary by their emissions. - Identify phenomenological barriers (frequency, motion, and vibration) and validate transition opportunities. - Demonstrate system performance over-the-air in mobile ground environments at extended ranges, under operationally representative motion and vibration. - Integrate tracking algorithms for target motion preparing for air-to-ground demonstration of capability. - Begin coordinating program transition with the Navy. ***FY 2017 Plans:*** - Design predictive algorithms for broadband channel estimation.	-	11.874	11.287

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Design control and feedback circuits to track high velocity targets based on target's emissions. - Integrate hardware for a dynamic airborne demonstration on multiple aircraft. - Demonstrate ReACT system and quantify performance against high velocity airborne target. - Continue coordinating program transition with the Navy.			
Title: High Energy Liquid Laser Area Defense System (HELLADS) ***Description:*** The goal of the High Energy Liquid Laser Area Defense System (HELLADS) program was to develop a high-energy laser weapon system that provides an order of magnitude reduction in weight compared to previous laser systems. HELLADS enabled high-energy lasers (HELs) to be integrated onto tactical aircraft and significantly increased engagement ranges compared to ground-based systems, in addition to enabling high precision/low collateral damage and rapid engagement of fleeting targets for both offensive and defensive missions. Advancements in beam control and other subsystems that are required for the practical integration of a laser weapon into existing tactical platforms were explored. With the assistance of the Services, the HELLADS program pursued the necessary analysis, coordination, and design activity for a prototype laser weapon system incorporating the HELLADS laser system and the ABC turret into air-, ground-, or sea-based tactical vehicles. The HELLADS 150 kilowatt (kW) class laser will transition to the Air Force. Additional technologies developed under this program will transition to the Services. ***FY 2015 Accomplishments:*** - Completed live fire tests against rocket and mortar fly-outs to demonstrate lethal laser power at mission-relevant ranges. - Completed live fire performance tests of laser weapon system against target sets representative of airborne missions, to include targeting of ground vehicles and self-defense against surface-to-air missiles. - Made system available for transition to the Services, and retain as a demonstration and test asset at the Army High Energy Laser System Test Facility (HELSTF).	13.073	-	-
Title: Robotics Challenge ***Description:*** The Robotics Challenge program sought to boost innovation in autonomous systems and expand platform utility through enhanced actuation, energy density, perception, locomotion, agile reconfiguration, and design efficiency. Program thrusts were centered on a progressive regimen of physical problem solving, real-time team oriented tasks, and dynamic adaptation designed to build "machine trust", especially when integrated with humans in a variety of operational environments. The Robotics Challenge program consisted of a series of obstacle course style challenge events that focused on technology solutions to demonstrate and test robot capabilities for disaster response. The program drove advances in power systems, agility and speed, precision in perception tied to platform coordination, dexterity, and impulsive power. Program objectives focused on technologies to expand mobility and extend endurance of unmanned platforms, advanced tactile and manipulation capabilities, and tools for cost effective design, validation, and construction of autonomous technology, and human-robot interaction. The 6.2 portion of this program was budgeted in PE 0602702E, Project TT-04. Anticipated Service users include the Army, Marines, and Special Forces.	4.000	-	-

Exhibit R-2A, **RDT&E Project Justification:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
FY 2015 Accomplishments: - Conducted DARPA Robotics Challenge Finals.			
Accomplishments/Planned Programs Subtotals	45.784	66.219	72.916

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-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
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*	

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
High Energy Liquid Laser Area Defense System (HELLADS)	C/Various	Various : Various	-	9.743		0.000		0.000		-		0.000	0	9.743	0
Resilient Synchronized Planning & Assessment for the Contested Environment	C/Various	Various : Various	-	10.187		16.060		22.322		-		22.322	Continuing	Continuing	Continuing
Retrodirective Arrays for Coherent Transmission (ReACT)	C/Various	Various : Various	-	0.000		10.937		9.584		-		9.584	Continuing	Continuing	Continuing
Robotics Challenge	C/Various	Various : Various	-	3.507		0.000		0.000		-		0.000	0	3.507	0
System of Systems Integration Technology and Experimentation (SoSITE)	C/Various	Various : Various	-	13.099		26.035		25.631		-		25.631	Continuing	Continuing	Continuing
		Subtotal	-	36.536		53.032		57.537		-		57.537	-	-	-

Support ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Government Support	MIPR	Various : Various	-	1.831		2.649		2.917		-		2.917	Continuing	Continuing	Continuing
		Subtotal	-	1.831		2.649		2.917		-		2.917	-	-	-

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
High Energy Liquid Laser Area Defense System (HELLADS)	MIPR	W04W USA WHITE SANDS MSL RANGE : NM	-	0.535	Oct 2014	0.000		0.000		-		0.000	0	0.535	0

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency			**Date:** February 2016
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*	

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Resilient Synchronized Planning & Assessment for the Contested Environment	C/CR	THE MITRE CORPORATION : VA	-	0.850	Mar 2015	1.077		2.491		-		2.491	Continuing	Continuing	Continuing
Robotics Challenge	C/Various	Various : Various	-	0.494		0.000		0.000		-		0.000	0	0.494	0
System of Systems Integration Technology and Experimentation (SoSITE)	C/Various	Various : Various	-	3.249		6.150		6.325		-		6.325	Continuing	Continuing	Continuing
		Subtotal	-	5.128		7.227		8.816		-		8.816	-	-	-

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	2.289		3.311		3.646		-		3.646	Continuing	Continuing	Continuing
		Subtotal	-	2.289		3.311		3.646		-		3.646	-	-	-

	Prior Years	FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	45.784		66.219		72.916		-		72.916	-	-	-

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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*

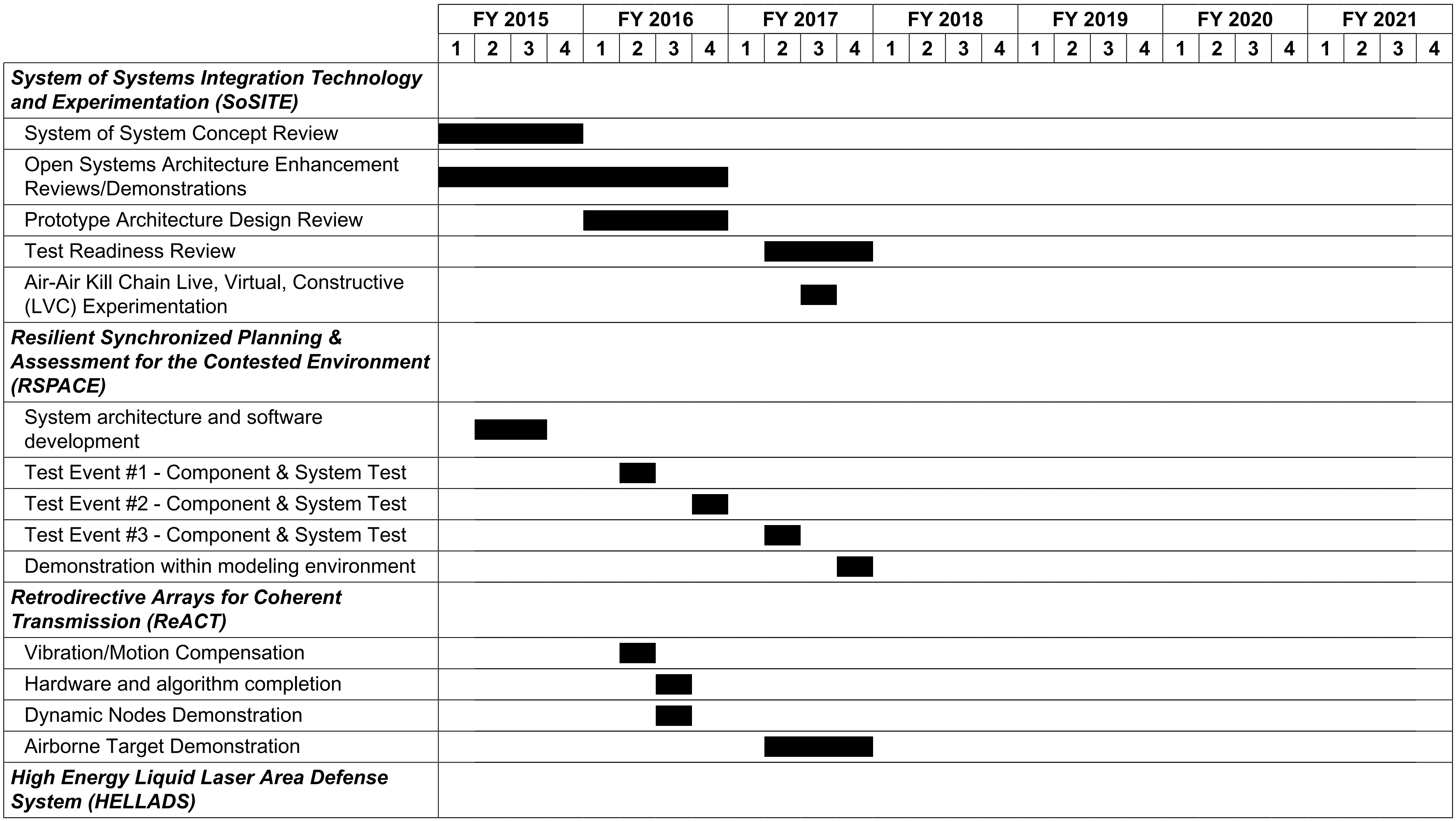

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency			**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-01 / *JOINT WARFARE SYSTEMS*	

	FY 2015				**FY 2016**				**FY 2017**				**FY 2018**				**FY 2019**				**FY 2020**				**FY 2021**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Live fire performance tests of laser weapons system	■																											
Baseline target engagements		■																										
Additional lethality testing for Services		■	■	■																								
Robotics Challenge																												
Conducted DARPA Robotics Challenge Finals			■																									

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
System of Systems Integration Technology and Experimentation (SoSITE)				
System of System Concept Review	1	2015	4	2015
Open Systems Architecture Enhancement Reviews/Demonstrations	1	2015	4	2016
Prototype Architecture Design Review	1	2016	4	2016
Test Readiness Review	2	2017	4	2017
Air-Air Kill Chain Live, Virtual, Constructive (LVC) Experimentation	3	2017	3	2017
Resilient Synchronized Planning & Assessment for the Contested Environment (RSPACE)				
System architecture and software development	2	2015	3	2015
Test Event #1 - Component & System Test	2	2016	2	2016
Test Event #2 - Component & System Test	4	2016	4	2016
Test Event #3 - Component & System Test	2	2017	2	2017
Demonstration within modeling environment	4	2017	4	2017
Retrodirective Arrays for Coherent Transmission (ReACT)				
Vibration/Motion Compensation	2	2016	2	2016
Hardware and algorithm completion	3	2016	3	2016
Dynamic Nodes Demonstration	3	2016	3	2016
Airborne Target Demonstration	2	2017	4	2017
High Energy Liquid Laser Area Defense System (HELLADS)				
Live fire performance tests of laser weapons system	1	2015	1	2015
Baseline target engagements	2	2015	2	2015
Additional lethality testing for Services	2	2015	4	2015

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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*

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Robotics Challenge				
Conducted DARPA Robotics Challenge Finals	3	2015	3	2015

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	Project (Number/Name) NET-02 / *MARITIME SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
NET-02: *MARITIME SYSTEMS*	-	72.980	119.401	138.303	-	138.303	126.321	162.344	145.301	135.301	-	-

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 2015	FY 2016	FY 2017
Title: Hydra	24.790	29.363	24.210

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 2015 Accomplishments:
- Completed concept designs for the modular enclosure and potential payloads.
- Began development of a prototype modular enclosure.
- Began development of undersea and air vehicle payloads.
- Demonstrated enabling technologies and subsystems.
- Conducted initial flight test of the air vehicle.

FY 2016 Plans:
- Build and test prototype modular enclosure.
- Complete preliminary design review for undersea payload.
- Complete component testing on undersea payload technologies.
- Complete critical design review for air vehicle payload.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Conduct flight tests of the air vehicle. ***FY 2017 Plans:*** - Construct and demonstrate a prototype modular enclosure. - Complete a full air vehicle flight test. - Launch air vehicle from modular enclosure.			
Title: Hybrid Multi Material Rotor Full Scale Demonstration (HyDem) ***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 2015 Accomplishments:*** - Conducted a Preliminary Design Review. - Completed manufacturing drawings and tooling. - Conducted a Critical Design Review. - Incorporated design lessons-learned from large scale vehicle (LSV) testing of scaled unit. - Continued structural building block testing. - Confirmed high-cycle fatigue endurance limit for structural material. - Initiated manufacturing of the full-scale propulsor component to be installed on a Virginia Class submarine. - Conducted a shock test of a large-scale model. ***FY 2016 Plans:*** - Complete structural building block testing. - Complete manufacturing of the full-scale propulsor component. - Deliver full-scale propulsor component to the Navy for integration into a Virginia Class submarine. - Assess structural and shock qualification of the propulsor component.	9.982	14.000	7.500

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Provide integration support for the propulsor component. - Complete shock building block testing. - Initiate development of advanced concepts seeking to improve performance and affordability. - Initiate long-term environment exposure monitoring test program. ***FY 2017 Plans:*** - Complete shock qualification of propulsor component. - Complete development of advanced concepts. - Transition long-term environmental exposure monitoring program to the Navy.			
Title: Tactical Undersea Network Architecture ***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 2015 Accomplishments:*** - Commenced system architecture design trade studies, modeling, and simulation. - Commenced small lightweight optical fiber development and fiber performance testing. - Assessed system deployment options; developed cost model. - Developed system component-level technologies and commenced scaled component-level testing. - Identified key system risks and technology trades. ***FY 2016 Plans:*** - Evaluate environmental condition's impact on system performance via modeling and simulation. - Complete system architecture design trade studies and preliminary designs.	13.384	19.500	22.173

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Continue fiber performance testing; demonstrate fiber survivability under at-sea conditions. - Conduct system-level performance modeling. - Complete component-level testing. - Commence prototype system design and plan for sea test. ***FY 2017 Plans:*** - Complete and evaluate prototype system design and design review. - Commence system fabrication and integration testing. - Continue at-sea system demonstration planning and coordination. - Demonstrate deployment and at-sea operation and survival.			
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 2015 Accomplishments:*** - Commenced platform and module design and technology assessments and system safety and effectiveness modeling. - Established baseline test platform architecture and conducted initial check-out testing. - Developed interface control documentation. - Developed model-based engineering environment for rapid trade analyses. - Conducted design trade studies to refine system architecture. - Conducted system performance modeling and simulation and small scale laboratory trials.	11.500	15.500	11.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Commenced system design safety certification and system engineering including test planning. ***FY 2016 Plans:*** - Complete component designs and design reviews. - Commence module development and fabrication. - Commence sub-system hardware and software testing and module integration. - Update system performance models and conduct initial at-sea testing. - Commence 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. - Commence at-sea demonstration planning, training, and support preparations. - Complete system integration and checkouts.			
Title: Positioning System for Deep Ocean Navigation (POSYDON)* ***Description:*** *Formerly Long-Range Undersea Navigation 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 triangulate its position. Technologies developed under this program will transition to the Navy. ***FY 2016 Plans:*** - Design and develop algorithms for accurately predicting acoustic signal propagation paths. - Develop the system concept of operations.	-	18.620	24.570

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Conduct at-sea experiments to validate analysis using a single source/receiver pair at basin-scale range to measure signal tracking accuracy and stability as well as signal acquisition techniques. ***FY 2017 Plans:*** - 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.			
Title: Mobile Offboard Command, Control and Attack (MOCCA) ***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, novel low probability of intercept/low probability of detection (LPI/LPD) communication signaling, and high energy density sub-systems compatible with deployable UUV packaging constraints. 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 Plans:*** - Begin preliminary design of hardware and software components. ***FY 2017 Plans:*** - Evaluate designs on compact acoustic projectors, UUV energy solutions, LPI/LPD communications link system components. - Develop subsystems including compact high output acoustic projector, UUV energy solutions, LPI/LPD communications link system. - Commence 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. - Initiate process for approval of temporary system integration into submarine systems for test and evaluation.	-	4.200	16.334
Title: Virtual Acoustic Microphone System (VAMS)	-	5.000	15.958

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
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 the laser projection of underwater acoustic sensor arrays with performance comparable to existing arrays. The VAMS approach, however, will allow the array to be adaptively reconfigured, 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 reconfigurable laser 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 Plans:*** - Evaluate core enabling technologies, including the application of high-speed sensor technology to increase the sensitivity of laser-based acoustic detection. ***FY 2017 Plans:*** - Initiate system design, which will demonstrate the required acoustic capabilities. - Initiate the development of advanced signal processing methods that will enable acoustic information extraction from the laser-based sensor and compensate for motion of the platform.			
Title: Cross Domain Maritime Surveillance and Targeting (CDMaST) ***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 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.	-	4.000	16.558

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
FY 2016 Plans: - Establish modeling and simulation environment to conduct high fidelity mission-level architecture analysis. ***FY 2017 Plans:*** - Develop baseline system of systems architecture. - Create concept design for system of systems live, virtual, and constructive test bed environment.			
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 intends to reverse the asymmetric advantage of this threat through the development of advanced standoff sensing from unmanned systems. Deep-ocean sonar nodes will be 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, will permit a scalable number of collaborative sensor platforms to detect and track submarines over large areas. At-sea demonstrations have shown that the detection capability is achievable. The program will continue to develop prototype systems that will evolve through additional at-sea testing. These tests will demonstrate the ability to integrate into the Navy's undersea systems responsible for anti-submarine warfare (ASW). The program seeks to achieve 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. This program will transition to the Navy. ***FY 2015 Accomplishments:*** - Designed and developed longer duration passive and active sonar nodes. - Conducted extended duration sonar demonstrations at sea against a target. - Demonstrated connectivity from seafloor node to remote shore station. - Integrated distributed communications with Navy systems for data transfer and Command, Control, Communications, Computers, and Intelligence (C4I). - Initiated test planning for passive and active sonar sea test. - Explored alternative concepts of operations and modified architectures of DASH system for other applications. - Initiated data collection experiments in other significant Navy operational areas to characterize DASH performance. ***FY 2016 Plans:*** - Conduct at-sea demonstrations of a distributed deep-ocean passive sonar barrier using multiple nodes for extended duration. - Conduct at-sea demonstrations of a mobile active sonar node.	13.324	9.218	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Perform data-driven signal processing development to improve automated sonar detection algorithms. - Provide analysis and data to support Navy utility assessments and studies to aid in transition. - Complete data collection experiments in other significant Navy operational areas to characterize DASH performance. - Continue to explore alternate techniques for long-range submarine detection and precision target tracking.			
Accomplishments/Planned Programs Subtotals	72.980	119.401	138.303

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-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016

Appropriation/Budget Activity	**R-1 Program Element (Number/Name)**	**Project (Number/Name)**
0400 / 3	PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	NET-02 / *MARITIME SYSTEMS*

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Hydra	C/CPFF	Oceaneering International, Inc. : MD	-	6.474	Jan 2015	0.646		0.000		-		0.000	Continuing	Continuing	Continuing
Hydra	C/CPFF	Raytheon Company : CA	-	8.437	Mar 2015	19.974		12.393		-		12.393	Continuing	Continuing	Continuing
Hydra	C/Various	Various : Various	-	7.647		6.101		5.100		-		5.100	Continuing	Continuing	Continuing
Hybrid Multi Material Rotor Full Scale Demonstration (HyDem)	C/CPFF	Goodrich Corporation : FL	-	6.465	Dec 2014	6.760		2.500		-		2.500	Continuing	Continuing	Continuing
Hybrid Multi Material Rotor Full Scale Demonstration (HyDem)	C/Various	Various : Various	-	2.619		5.980		4.325		-		4.325	Continuing	Continuing	Continuing
Tactical Undersea Network Architecture	C/Various	Various : Various	-	11.449		14.560		18.815		-		18.815	Continuing	Continuing	Continuing
Blue Wolf	C/Various	Various : Various	-	10.465		14.505		9.590		-		9.590	Continuing	Continuing	Continuing
Positioning System for Deep Ocean Navigation (POSYDON)*	C/CPFF	Various : Various	-	0.000		11.903		23.134		-		23.134	Continuing	Continuing	Continuing
Positioning System for Deep Ocean Navigation (POSYDON)*	C/CPFF	THE CHARLES STARK DRAPER LABORATORY INC : MA	-	0.000		5.757		0.000		-		0.000	0	5.757	0
Mobile Offboard Command, Control and Attack (MOCCA)	C/Various	Various : Various	-	0.000		3.430		15.122		-		15.122	Continuing	Continuing	Continuing
Virtual Acoustic Microphone System (VAMS)	C/Various	Various : Various	-	0.000		3.950		11.283		-		11.283	Continuing	Continuing	Continuing
Cross Domain Maritime Surveillance and Targeting (CDMaST)	C/Various	Various : Various	-	0.000		3.310		15.224		-		15.224	Continuing	Continuing	Continuing

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

Product Development ($ in Millions)

				FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total			
Cost Category Item	**Contract Method & Type**	**Performing Activity & Location**	**Prior Years**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Cost To Complete**	**Total Cost**	**Target Value of Contract**
Distributed Agile Submarine Hunting (DASH)	SS/CPFF	Various : Various	-	10.926		7.290		0.000		-		0.000	0	18.216	0
		Subtotal	-	64.482		104.166		117.486		-		117.486	-	-	-

Support ($ in Millions)

				FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total			
Cost Category Item	**Contract Method & Type**	**Performing Activity & Location**	**Prior Years**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Cost To Complete**	**Total Cost**	**Target Value of Contract**
Government Support	C/Various	Various : Various	-	2.919		4.776		5.532		-		5.532	Continuing	Continuing	Continuing
		Subtotal	-	2.919		4.776		5.532		-		5.532	-	-	-

Test and Evaluation ($ in Millions)

				FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total			
Cost Category Item	**Contract Method & Type**	**Performing Activity & Location**	**Prior Years**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Award Date**	**Cost**	**Cost To Complete**	**Total Cost**	**Target Value of Contract**
Hydra	C/Various	Various : Various	-	0.000		0.000		2.725		-		2.725	Continuing	Continuing	Continuing
Hybrid Multi Material Rotor Full Scale Demonstration (HyDem)	C/Various	Various : Various	-	0.000		0.000		1.750		-		1.750	Continuing	Continuing	Continuing
Tactical Undersea Network Architecture	MIPR	Various : Various	-	0.562		3.195		0.000		-		0.000	0	3.757	0
Positioning System for Deep Ocean Navigation (POSYDON)*	MIPR	Various : Various	-	0.000		0.175		0.650		-		0.650	Continuing	Continuing	Continuing
Mobile Offboard Command, Control and Attack (MOCCA)	C/TBD	Various : Various	-	0.000		0.000		0.200		-		0.200	Continuing	Continuing	Continuing
Virtual Acoustic Microphone System (VAMS)	C/TBD	Various : Various	-	0.000		0.000		3.045		-		3.045	Continuing	Continuing	Continuing

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Distributed Agile Submarine Hunting (DASH)	C/Various	Various : Various	-	1.368		1.118		0.000		-		0.000	0	2.486	0
		Subtotal	-	1.930		4.488		8.370		-		8.370	-	-	-

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	3.649		5.971		6.915		-		6.915	Continuing	Continuing	Continuing
		Subtotal	-	3.649		5.971		6.915		-		6.915	-	-	-

	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	72.980	119.401	138.303	-	138.303	-	-	-

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Hydra																												
Modular Enclosure Preliminary Design Review			■																									
Air Vehicle Initial Flight Test				■																								
Test Prototype Modular Enclosure					■																							
Critical Design Review of Undersea Payload and Air Vehicle Payload						■																						
Complete a Full Air Vehicle Flight Test										■																		
Demonstrate Full Undersea Payload Demonstration from the Modular Enclosure												■																
Hybrid Multi Material Rotor Full Scale Demonstration (HyDem)																												
Preliminary Design Review		■																										
Critical Design Review			■																									
Deliver Full Scale Component to Navy							■																					
Support Propulsor Integration on VIRGINIA Class Submarine							■	■	■	■																		
Support Propulsor Testing											■	■																
Tactical Undersea Network Architecture																												
System architecture design studies		■																										
Preliminary Design Review of system architecture					■																							
Component Testing					■																							
Software Design Review (SDR)										■																		
At-sea demonstration												■																
Blue Wolf																												

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

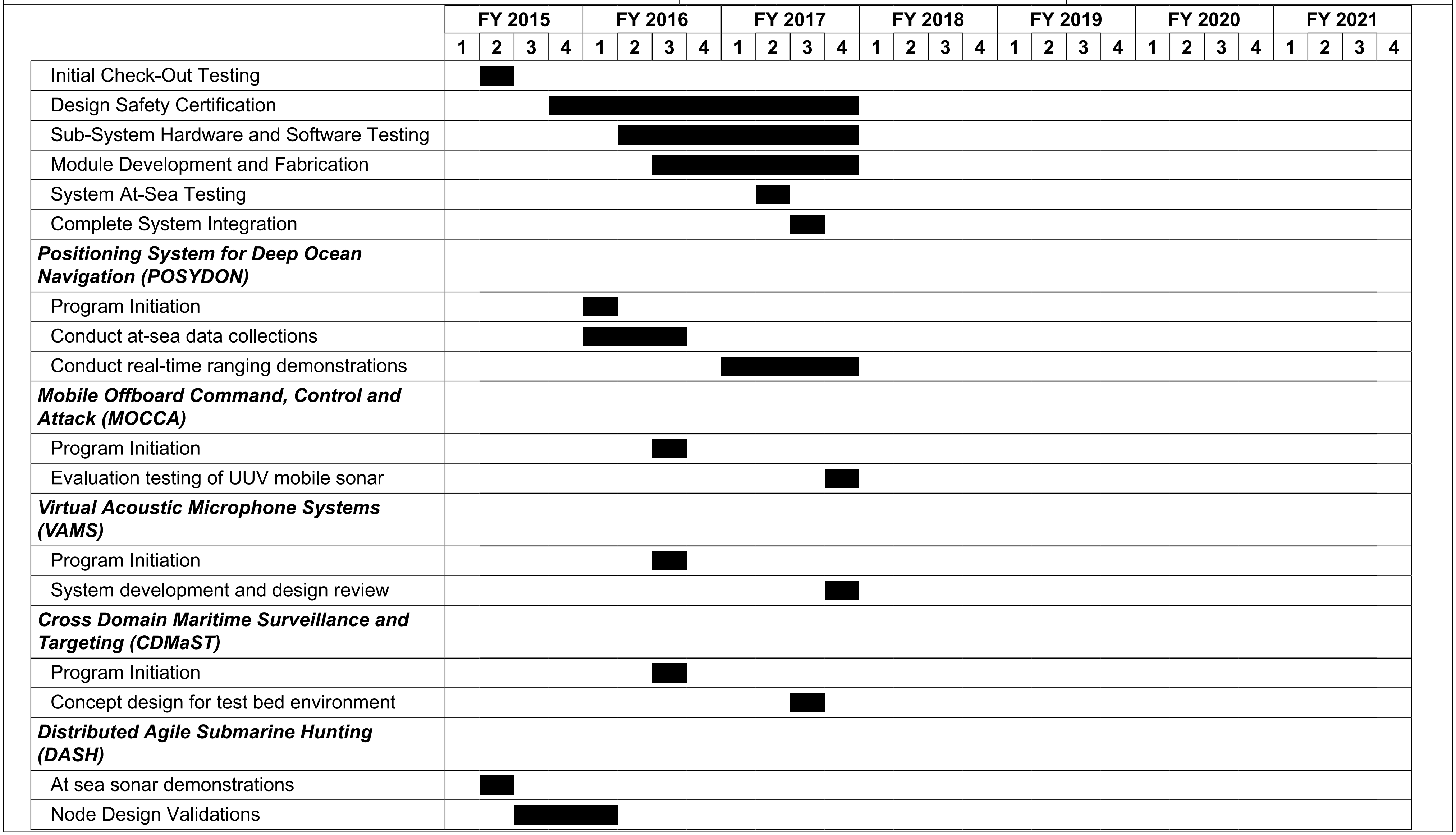

Exhibit R-4, **RDT&E Schedule Profile:** PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016

Appropriation/Budget Activity	**R-1 Program Element (Number/Name)**	**Project (Number/Name)**
0400 **/** 3	PE 0603766E **/** *NETWORK-CENTRIC WARFARE TECHNOLOGY*	NET-02 **/** *MARITIME SYSTEMS*

	FY 2015				**FY 2016**				**FY 2017**				**FY 2018**				**FY 2019**				**FY 2020**				**FY 2021**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
At sea mobile active sonar demonstrations						■	■	■																				
Node System demonstration								■																				

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Hydra				
Modular Enclosure Preliminary Design Review	3	2015	3	2015
Air Vehicle Initial Flight Test	4	2015	4	2015
Test Prototype Modular Enclosure	1	2016	1	2016
Critical Design Review of Undersea Payload and Air Vehicle Payload	2	2016	2	2016
Complete a Full Air Vehicle Flight Test	2	2017	2	2017
Demonstrate Full Undersea Payload Demonstration from the Modular Enclosure	4	2017	4	2017
Hybrid Multi Material Rotor Full Scale Demonstration (HyDem)				
Preliminary Design Review	2	2015	2	2015
Critical Design Review	3	2015	3	2015
Deliver Full Scale Component to Navy	3	2016	3	2016
Support Propulsor Integration on VIRGINIA Class Submarine	3	2016	2	2017
Support Propulsor Testing	3	2017	4	2017
Tactical Undersea Network Architecture				
System architecture design studies	2	2015	2	2015
Preliminary Design Review of system architecture	1	2016	1	2016
Component Testing	1	2016	1	2016
Software Design Review (SDR)	2	2017	2	2017
At-sea demonstration	4	2017	4	2017
Blue Wolf				
Initial Check-Out Testing	2	2015	2	2015
Design Safety Certification	4	2015	4	2017

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Sub-System Hardware and Software Testing	2	2016	4	2017
Module Development and Fabrication	3	2016	4	2017
System At-Sea Testing	2	2017	2	2017
Complete System Integration	3	2017	3	2017
Positioning System for Deep Ocean Navigation (POSYDON)				
Program Initiation	1	2016	1	2016
Conduct at-sea data collections	1	2016	3	2016
Conduct real-time ranging demonstrations	1	2017	4	2017
Mobile Offboard Command, Control and Attack (MOCCA)				
Program Initiation	3	2016	3	2016
Evaluation testing of UUV mobile sonar	4	2017	4	2017
Virtual Acoustic Microphone Systems (VAMS)				
Program Initiation	3	2016	3	2016
System development and design review	4	2017	4	2017
Cross Domain Maritime Surveillance and Targeting (CDMaST)				
Program Initiation	3	2016	3	2016
Concept design for test bed environment	3	2017	3	2017
Distributed Agile Submarine Hunting (DASH)				
At sea sonar demonstrations	2	2015	2	2015
Node Design Validations	3	2015	1	2016
At sea mobile active sonar demonstrations	2	2016	4	2016
Node System demonstration	4	2016	4	2016

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	231.559	240.241	217.675	-	217.675	172.150	85.796	63.000	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 2015**	**FY 2016**	**FY 2017**
Title: Classified DARPA Program ***Description:*** This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2015 Accomplishments:*** Details will be provided under separate cover. ***FY 2016 Plans:*** Details will be provided under separate cover. ***FY 2017 Plans:*** Details will be provided under separate cover.	231.559	240.241	217.675
Accomplishments/Planned Programs Subtotals	231.559	240.241	217.675

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Details will be provided under separate cover.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	283.905	240.127	241.288	-	241.288	207.325	197.278	236.505	270.554	-	-
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	32.266	18.121	19.027	-	19.027	11.331	11.527	16.401	16.401	-	-
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	115.315	116.396	145.732	-	145.732	149.194	167.876	215.104	254.153	-	-
SEN-03: *EXPLOITATION SYSTEMS*	-	48.924	13.411	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
SEN-06: *SENSOR TECHNOLOGY*	-	87.400	92.199	76.529	-	76.529	46.800	17.875	5.000	0.000	-	-

A. Mission Description and Budget Item Justification

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

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

The Sensors and Processing Systems project develops and demonstrates the advanced sensor processing technologies and systems necessary for intelligence surveillance and reconnaissance (ISR) missions. The project is primarily driven by four needs: 1) providing day-night ISR capabilities against the entire range of potential targets; 2) countering camouflage, concealment, and deception of mobile ground targets; 3) detecting and identifying objects of interest/targets across wide geographic areas in near-real-time; and 4) enabling reliable identification, precision fire control tracking, timely engagement, and accurate battle damage assessment of ground targets.

The Exploitation Systems project develops algorithms, software, and information processing systems to extract information from massive intelligence, surveillance, and reconnaissance (ISR) datasets. In particular, it develops 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.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	302.821	257.127	275.921	-	275.921
Current President's Budget	283.905	240.127	241.288	-	241.288
Total Adjustments	-18.916	-17.000	-34.633	-	-34.633
• Congressional General Reductions	0.000	-6.000			
• Congressional Directed Reductions	0.000	-11.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-9.693	0.000			
• SBIR/STTR Transfer	-9.223	0.000			
• TotalOtherAdjustments	-	-	-34.633	-	-34.633

Change Summary Explanation

FY 2015: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2016: Decrease reflects congressional reduction.
FY 2017: Decrease reflects completion of Insight and drawdown of classified programs.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	32.266	18.121	19.027	-	19.027	11.331	11.527	16.401	16.401	-	-

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 2015	FY 2016	FY 2017
Title: Multi-Optical Sensing (MOS)*	18.060	18.121	19.027
Description: *Formerly Multi-Function Optical Sensing (MOS) 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 2015 Accomplishments:*** - Completed initial capability demonstrations, which collected target imagery used to baseline simulations. - Initiated the development of the first-generation prototype system. - Incorporated advanced data processing and target tracking algorithms into the sensor processing chain. - Demonstrated capability of active focal plane arrays and variable waveform lasers to meet the desired detection performance. - Initiated packaging activity for the incorporation of the developed active focal plane arrays and variable waveform lasers into the second-generation architecture.			

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Developed a hardware traceability strategy for the second-generation prototype sensor, which will be part of a roadmap for the development of a fully operational system. ***FY 2016 Plans:*** - Complete the development of the first-generation prototype system. - Perform air-to-air demonstrations with the first-generation prototype system. - Initiate 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. - Demonstrate the full capability of the second-generation prototype system out to operational ranges.			
Title: Adaptable Navigation Systems (ANS) ***Description:*** The Adaptable Navigation Systems (ANS) program provided the U.S. warfighter with the ability to effectively navigate challenging environments including when Global Positioning System (GPS) is unavailable due to hostile action (jamming) or blockage by structures, foliage, or other environmental obstacles. The ANS approach relied on three major technology innovations. The first was the development of a new type of inertial measurement unit (IMU) that required fewer GPS position fixes. Using cold atom technology, this IMU exceeds the performance of strategic-grade IMUs, with comparable size, weight, and power (SWaP). The second innovation used Signals of Opportunity (SoOp) from a variety of ground-, air-, and space-based sources, as well as natural SoOps to reduce dependency on GPS position fixes. The third technology innovation allowed SoOp-based position information to be combined with inertial and other sensors to enable flexible navigation systems that can be reconfigured in the field to support any platform or environment. This capability enhanced new advanced component technology for positioning, navigation, and timing (PNT) emerging from other programs in the form of Micro Electro-Mechanical System devices, clocks, and new aiding sensors. Recent advances in mathematics, data abstraction, and network architectures built upon these capabilities by enabling "plug-and-play" integration of both existing and future navigation components and processing to allow real-time reconfiguration of navigation systems. Major improvements in navigation accuracy and system cost were also realized. Potential transition partners include all Services, with emphasis on platforms and users that must operate in multiple environments, such as Naval forces. ***FY 2015 Accomplishments:*** - Designed, built, and evaluated components of a cold atom interferometer for inertial sensing. - Demonstrated the navigation performance, independent of GPS, of the integrated ANS system, comprised of various sensors, including IMUs and SoOp receivers, and a sensor fusion processor, on multiple sea-, air-, and land-based platforms.	11.482	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Integrated additional ship-based non-navigation sensors into an ANS system and demonstrated GPS-independent navigation at sea to effect transition to the Navy.			
Title: Adaptable, Low Cost Sensors (ADAPT) ***Description:*** The objective of the Adaptable, Low Cost Sensors (ADAPT) program was to leverage commercial technology and manufacturing techniques to improve the development time and significantly reduce the cost of sensors and sensor systems. Currently, military sensors are designed and developed with unique, mission-specific hardware and software capability requirements in a single, fully integrated device. This approach significantly increases both the cost and difficulty of meeting continuously changing requirements and upgrades. Commercial processes, such as those used in the smart phone industry, create reference designs for common system functions and features to accelerate system development time. This makes changing requirements and completing upgrades far simpler. Adopting these commercial processes enables a mission-independent, designed-to-cost "commercial smart core" that can be combined with an appliqué of mission-specific hardware to provide low-cost, independently upgradable, and previously infeasible sensor system distribution capabilities. The ADAPT Smart Munitions effort has applied ADAPT's sensing, processing, communications, and location capabilities to provide positive identification and man-in-the-loop control of distributed, unattended ground sensor systems. It also developed a reference design to demonstrate capability and develop tactics for unattended sensors. This program will transition to the Army and Navy. ***FY 2015 Accomplishments:*** - Field tested and demonstrated mobile coordinated device operation using ADAPT reference designs (Smart Munitions and UAVs). - Investigated alternative low-cost sensor designs for other small form factor unmanned military platforms. - Completed development and testing of the ADAPT reference designs. - Transitioned reference designs to the Army and Navy.	2.724	-	-
Accomplishments/Planned Programs Subtotals	32.266	18.121	19.027

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-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency			**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
ADAPT	C/Various	Various : Various	-	1.755		0.000		0.000		-		0.000	0	1.755	0
Adaptable Navigation Systems	C/Various	Various : Various	-	7.692		0.000		0.000		-		0.000	0	7.692	0
Multi Optical Sensing	C/CPFF	Various : Various	-	2.547		5.475		5.655		-		5.655	Continuing	Continuing	Continuing
Multi Optical Sensing	C/CPFF	BAE SYSTEMS INTEGRATION I : NH	-	7.014	Mar 2015	0.000		0.000		-		0.000	0	7.014	0
Multi Optical Sensing	C/CPFF	RAYTHEON COMPANY : CA	-	7.729	Sep 2015	10.624		11.660		-		11.660	Continuing	Continuing	Continuing
		Subtotal	-	26.737		16.099		17.315		-		17.315	-	-	-

Support ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Government Support	C/Various	Various : Various	-	1.291		0.725		0.761		-		0.761	Continuing	Continuing	Continuing
		Subtotal	-	1.291		0.725		0.761		-		0.761	-	-	-

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
ADAPT	MIPR	Various : Various	-	0.186		0.000		0.000		-		0.000	0	0.186	0
Adaptable Navigation Systems	MIPR	Various : Various	-	1.945		0.000		0.000		-		0.000	0	1.945	0
Multi Optical Sensing	SS/CPFF	MIT LINCOLN LABORATORY : MA	-	0.494	Apr 2015	0.391		0.000		-		0.000	0	0.885	0
		Subtotal	-	2.625		0.391		0.000		-		0.000	0.000	3.016	0.000

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	1.613		0.906		0.951		-		0.951	Continuing	Continuing	Continuing
		Subtotal	-	1.613		0.906		0.951		-		0.951	-	-	-

	Prior Years	FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	32.266		18.121		19.027		-		19.027	-	-	-

Remarks

Exhibit R-4, **RDT&E Schedule Profile:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 **/** 3	**R-1 Program Element (Number/Name)** PE 0603767E **/** *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 **/** *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*

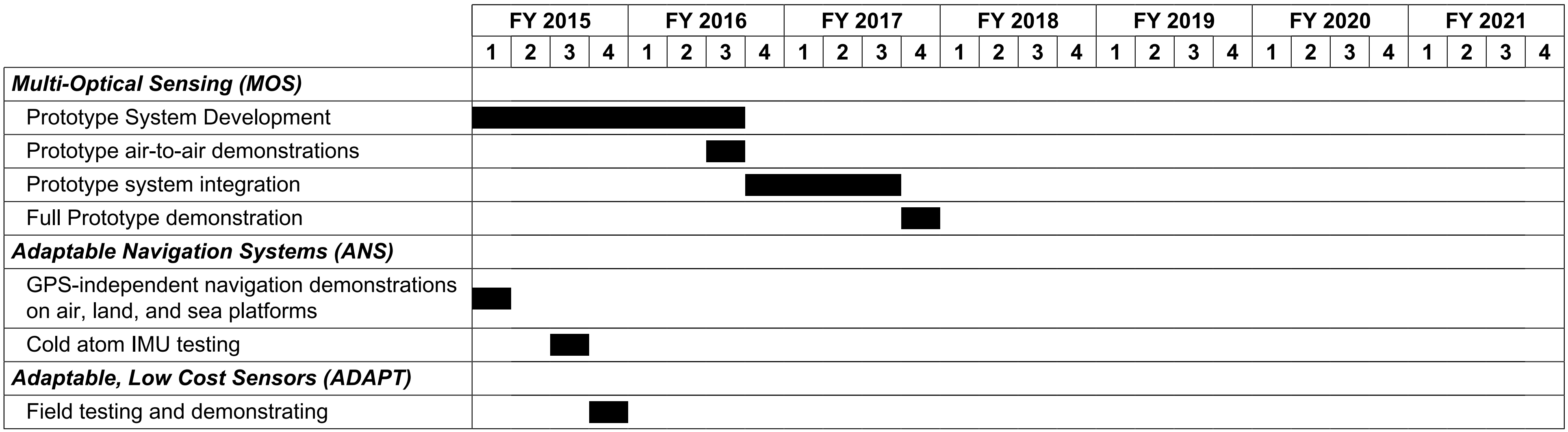

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Multi-Optical Sensing (MOS)				
Prototype System Development	1	2015	3	2016
Prototype air-to-air demonstrations	3	2016	3	2016
Prototype system integration	4	2016	3	2017
Full Prototype demonstration	4	2017	4	2017
Adaptable Navigation Systems (ANS)				
GPS-independent navigation demonstrations on air, land, and sea platforms	1	2015	1	2015
Cold atom IMU testing	3	2015	3	2015
Adaptable, Low Cost Sensors (ADAPT)				
Field testing and demonstrating	4	2015	4	2015

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	115.315	116.396	145.732	-	145.732	149.194	167.876	215.104	254.153	-	-

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 2015	FY 2016	FY 2017
Title: Adaptive Radar Countermeasures (ARC) ***Description:*** The goal of the Adaptive Radar Countermeasures (ARC) program is to provide effective electronic countermeasure (ECM) techniques against new or unknown threat radars. Current airborne electronic warfare (EW) systems rely on the ability to uniquely identify a threat radar system to apply an appropriate preprogrammed countermeasure technique which can take many months to develop. Countering radar systems is increasingly challenging as digitally programmed radars exhibit novel behaviors and agile waveform characteristics. ARC will develop new processing techniques and algorithms that adapt in real-time to generate suitable countermeasures. Using techniques such as state modeling, machine learning, and system probing, ARC will learn the behavior of the threat system, then choose and implement an appropriate countermeasure strategy. The program is planned for transition to Air Force, Navy, and Marine Corps airborne EW systems. ***FY 2015 Accomplishments:*** - Refined and integrated component algorithms for end-to-end system testing in simulation. - Developed adaptive radar threat models for use in testing which emulate future adversary radar capabilities that are expected to challenge current baseline EW systems. - Began porting software algorithms onto transition partner provided baseline EW systems to demonstrate enhanced performance against unknown or ambiguous threat radars. ***FY 2016 Plans:***	26.475	20.512	19.487

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Complete real-time software and firmware implementation of all major algorithm modules on transition partner provided baseline EW systems. - Refine adaptive radar threat models for use in testing which emulate future adversary radar capabilities that are expected to challenge current baseline EW systems. - Demonstrate real-time prototype systems by effectively operating against unanticipated or ambiguous radar signals in a hardware-in-the-loop laboratory environment. ***FY 2017 Plans:*** - Develop detailed flight test plans in concert with relevant programs of record and Service partners. - Identify test ranges and relevant assets which can emulate modern unanticipated and ambiguous radar signals in an open-air testing environment. - Update software algorithms testing robustness to realistic RF test conditions using emulation in real-time laboratory testing and stationary open-air tests.			
Title: Spatial, Temporal and Orientation Information for Contested Environments (STOIC) ***Description:*** Building on technologies developed in the Adaptable Navigation Systems (ANS) program, budgeted in PE 0603767E, Project SEN-01, 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 2015 Accomplishments:*** - Began developing a compact optical clock that maintains GPS-level time for over a year. - Began developing a wireless precision time transfer system that provides better than GPS-level performance using tactical data links. - Began developing jam-proof PNT systems that provide GPS-level performance in contested environments. ***FY 2016 Plans:*** - Complete prototype components of optical clocks. - Complete detailed design and begin development of compact optical clocks. - Develop prototype components and systems for enabling precision time transfer independent of GPS. - Complete detailed design and begin development of GPS-independent precision time transfer systems.	18.425	23.500	21.365

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop prototype jam-proof PNT system components (signal transmit and receive) for achieving GPS-level positioning performance in contested environments. - Complete detailed design and begin development of jam-proof PNT system based on very low frequency (VLF) transmitters and waveforms. ***FY 2017 Plans:*** - Commence integration and testing of compact optical clocks. - Complete development 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.			
Title: Automatic Target Recognition (ATR) Technology ***Description:*** Automatic Target Recognition (ATR) systems provide the capability to detect, identify, and track high value targets from collected sensor data. Current ATRs are typically designed for specific sensors and static due to pre-programmed target lists and operating mode, limiting mission execution capabilities. Extending ATR Technology to accommodate sensor upgrades or include new emerging targets can be costly and time consuming. The objective of the ATR Technology program is to develop technologies that reduce operation limitations while also providing significant performance improvements, dramatically reduced development times, and reduced life cycle maintenance costs. Recent breakthroughs in deep learning, sparse representations, manifold learning, and embedded systems offer promise for dramatic improvements in ATR Technology. The program will focus on three core areas: (1) development of on-line adaptive algorithms that enable performance-driven sensing and ATR technology; (2) recognition technology that enables rapid incorporation of new targets; and (3) technologies that dramatically reduce required data rates, processing times, and the overall hardware and software footprint of ATR systems. ATR technology developed under the program is planned for transition to the Services. ***FY 2015 Accomplishments:*** - Developed a modeling and simulation framework for testing and evaluating performance-driven ATR systems. - Established baseline performance for existing radar ATR algorithms against challenge problem data sets. - Designed and executed a data collection experiment to provide additional data for algorithm development and testing. - Initiated development of advanced algorithms that support signature generalization and reduced signature database complexity. ***FY 2016 Plans:*** - Initiate design of an embedded real-time, low-cost radar ATR processor that incorporates advanced ATR algorithms and uses commercial mobile embedded computing platforms. - Design and execute additional data collection experiments for continued algorithm development and testing. - Continue to improve ATR algorithm performance, including decoy rejection and false target rejection. ***FY 2017 Plans:***	11.500	18.000	24.759

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
- Develop adaptable ATR algorithms to rapidly learn new targets with minimal measured data and evaluate algorithm learning rate. - 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.			
Title: Advanced Scanning Technology for Imaging Radars (ASTIR) ***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, 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 Plans:*** - Develop sensor design concepts and define processing requirements. - Build prototype electronic sub-reflector beam-steering systems and conduct tests to characterize performance and validate approach. - Conduct mission studies and determine 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.	-	9.988	13.985
Title: Small Satellite Sensors	-	8.000	24.478

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
Description: Building upon low-cost and small form factor sensor research conducted under DARPA's Adaptable, Low Cost Sensors (ADAPT) and Multi-Optical Sensing (MOS) programs (budgeted in PE 0603767E, Project SEN-01), 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 lb) 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. ***FY 2016 Plans:*** - Develop conceptual designs for EO/IR sensor and inter-satellite communications link subsystems. - Develop software performance models for candidate sensor systems, and perform laboratory or airborne testing to improve model fidelity and assist in design of flight hardware. - Begin design of experimental sensor payloads compatible with a small satellite bus, and perform preliminary design review. - Begin development of lightweight and low-power inter-satellite communications links suitable for providing high-bandwidth crosslinks for 100 lb class satellites. - Investigate 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 a preliminary design review. - Complete construction of the 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.			
Title: Seeker Cost Transformation (SECTR)* ***Description:*** *Formerly Low Cost Seeker	-	8.000	20.658

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
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 ADAPT program (budgeted in PE 0603767E, Project SEN-01). 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 Plans:*** - Initiate development of core seeker system engineering design. - Initiate development of open seeker standard interfaces. - Develop small size, weight, and power (SWaP) and cost sensor and processing unit. - Design novel target recognition algorithms. - Design GPS-free image navigation and processing sensor and algorithm. - Perform initial hardware-in-the-loop (HWIL) test for GPS-free navigation unit. - Perform initial HWIL test for target recognition algorithms. ***FY 2017 Plans:*** - Conduct laboratory demonstrations of sensor/processing unit. - Conduct captive flight test of small SWaP sensor/processing unit. - Conduct laboratory demonstrations of GPS-free navigation algorithms. - Conduct laboratory demonstration of target recognition algorithms. - Integrate GPS-free navigation algorithm and target recognition algorithms into the small SWaP sensors/processing unit. - Complete and distribute seeker open standard interfaces.			
Title: Unbanded SPectrum operatIoNs (U-SPIN) ***Description:*** The goal of the Unbanded SPectrum operatIoNs (U-SPIN) program is to develop technologies which enable interoperability of multiple spectrum objectives simultaneously. Currently, U.S. forces divide the RF spectrum into "bands" to deconflict specific functions which are considered incompatible with one another (for example, communications, electronic warfare, signals intelligence, and RADAR). This approach relies on a static RF environment and accurate intelligence about	-	-	7.000

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
the opposing force's spectrum capabilities and allocations. It also enables the enemy to accurately predict where and what our spectrum functions will be. U-SPIN will demonstrate the ability to dynamically co-design the previously incompatible functions on-the-fly using learned knowledge about the RF environment. ***FY 2017 Plans:*** - Initiate algorithmic study of techniques that can achieve multiple spectrum objectives simultaneously. - Select best of breed application of technology (achieving at least two functions simultaneously) and demonstrate proof of concept in a laboratory setting.			
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 in this PE, 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 their associated airframe integration; (3) wide-band agile electronics to support converged missions over those apertures; and (4) software tools for the control, coordination, and scheduling of RF functions and payloads at the element level to maximize overall task performance. This capability can be adapted to address diverse missions. Technology developed under this program will transition to the Services. ***FY 2017 Plans:*** - Assemble requirements to provide an abstraction of underlying software and hardware architectures. - Commence design of modular architecture for agile, collaborative converged RF systems. - Commence design of RF apertures and associated airframe integration, and agile low-power wide-band RF electronics suitable for an RF payload on low-cost platforms/UAVs. - Commence development of software for controlling and scheduling RF hardware (including processor) to carry out the desired RF functions.	-	-	14.000
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, enroute navigation, lethality, and survivability. Building on previous RF sensors advancements, the program will seek to eliminate many redundant RF elements of current	12.075	6.385	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015**	**FY 2016**	**FY 2017**
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 and Marines. ***FY 2015 Accomplishments:*** - Demonstrated utility of software development kit through third-party programming. - Selected test platform and began modifications on Army helicopter for flight testing ARMS sensor. - Investigated alternative imaging radar architectures to further reduce size, weight, power, and cost. - Successfully built two unique tile prototype designs and selected final design for demonstration array. ***FY 2016 Plans:*** - Conduct laboratory and field demonstrations with integrated ARMS, synthetic vision backbone, other potential collision avoidance sensors and multifunction software development kit. - Demonstrate DVE landing, takeoff, Ground Moving Target Indicator (GMTI), and Synthetic Aperture Radar (SAR) modes of operation. - Conduct flight tests of ARMS integrated with synthetic vision system on an Army helicopter in cooperation with CERDEC and AMRDEC. - Transition DVE system to the Army. - Further explore RF technologies to determine feasibility of capability convergence.			
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 will provide 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).	18.847	12.250	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
FY 2015 Accomplishments: - Completed development and testing of prototype high power amplifier. - Demonstrated the integration of low power transmitter and receiver components into sensor and conducted over-the-air testing to validate system performance. - Integrated phenomenology data into scene simulator and generated data for demonstration of algorithm performance. ***FY 2016 Plans:*** - Complete development and unit-level testing of flightworthy high power amplifier. - Integrate hardware into a sensor control system (gimbal) and demonstrate performance in a laboratory scenario, and in over-the-air testing against calibration targets. - Integrate hardware and gimbal on a surrogate aircraft. - Begin flight tests to demonstrate ViSAR performance in comparison to Electro-Optic sensors. - Conduct flight demonstrations in cooperation with AFRL and AFSOC.			
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 can provide 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 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 SOCOM. ***FY 2015 Accomplishments:*** - Continued the development of a short-range 3-D imaging system. - Completed ground demonstrations of the moderate and long-range 3-D imaging systems, including testing and demonstration of critical subsystem components. - Completed a packaging study and testing of the MIST high-energy pulsed laser.	22.493	9.761	-

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Initiated the development of a mountain-to-ground demonstration capability for the moderate-range 3-D imaging system. ***FY 2016 Plans:*** - Complete the development of the short-range 3-D imaging system. - Demonstrate the capabilities of the completed short-range 3-D imaging system - Complete the development of the mountain-to-ground demonstration capability for the moderate-range 3-D imaging system. - Conduct mountain-to-ground demonstrations of the moderate-range 3-D imaging system. - Transition the short-range and moderate-range 3-D imaging system to the Services and SOCOM.			
Title: Behavioral Learning for Adaptive Electronic Warfare (BLADE) ***Description:*** The Behavioral Learning for Adaptive Electronic Warfare (BLADE) program developed the capability to jam adaptive and rapidly evolving wireless communication threats in tactical environments and at tactically-relevant timescales. This has changed the paradigm for responding to evolving threats from lab-based manual development to an adaptive in-the-field systems approach. When an unknown or adaptive communication threat appears in theater, BLADE dynamically characterized the communication network, synthesized an effective countering technique, and evaluated jamming effectiveness by iteratively probing, learning, and adapting to the threat. An optimization process tailored real-time responses to specific threats, producing a countermeasure waveform that maximizes jam effectiveness while minimizing the required jamming resources. BLADE enabled the rapid defeat of new communication threats and provided the warfighter with real-time feedback on jam effectiveness. The program transitioned to the U.S. Army Communications-Electronic RDT&E Center, Intelligence and Information Warfighter Directorate for further maturation and hardening. ***FY 2015 Accomplishments:*** - Tested and evaluated ground-based and airborne prototype systems in an operationally relevant over-the-air environment featuring agile and commercial communications threat networks. - Quantified the minimum hardware requirements, including processing and memory, necessary to execute the BLADE algorithms on transition platforms. - Transitioned BLADE components to U.S. Army Communications-Electronic RDT&E Center Intelligence and Information Warfare Directorate. - Executed an Airborne demonstration against tactically relevant threat networks at Electronics Proving Ground, Ft. Huachuca, AZ, to transition partners.	5.500	-	-
Accomplishments/Planned Programs Subtotals	115.315	116.396	145.732

C. Other Program Funding Summary ($ in Millions)

N/A

Exhibit R-2A, **RDT&E Project Justification:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

C. Other Program Funding Summary ($ in Millions)

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency			**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*	

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Adaptive Radar Countermeasures (ARC)	C/CPFF	Leidos : VA	-	8.450	Dec 2015	8.456		9.265		-		9.265	Continuing	Continuing	Continuing
Adaptive Radar Countermeasures (ARC)	C/CPFF	BAE : NH	-	9.350	Nov 2015	0.224		0.520		-		0.520	Continuing	Continuing	Continuing
Adaptive Radar Countermeasures (ARC)	C/CPFF	Various : Various	-	7.403		9.692		7.742		-		7.742	Continuing	Continuing	Continuing
Spatial, Temporal and Orientation Information for Contested Environments	C/Various	Various : Various	-	12.128		20.226		16.829		-		16.829	Continuing	Continuing	Continuing
Spatial, Temporal and Orientation Information for Contested Environments	C/CPFF	ROCKWELL COLLINS,INC. : IA	-	5.391	Apr 2015	0.000		0.000		-		0.000	0	5.391	0
Automatic Target Recognition (ATR) Technology	C/Various	Various : Various	-	8.934		15.853		22.730		-		22.730	Continuing	Continuing	Continuing
Advanced Scanning Technology for Imaging Radars (ASTIR)	C/Various	Various : Various	-	0.000		9.694		11.903		-		11.903	Continuing	Continuing	Continuing
Small Satellite Sensors	C/Various	Various : Various	-	0.000		7.823		22.763		-		22.763	Continuing	Continuing	Continuing
Seeker Cost Transformation (SECTR)*	C/CPFF	Various : Various	-	0.000		6.888		17.935		-		17.935	Continuing	Continuing	Continuing
Unbanded SPectrum operatIoNs (U-SPIN)	C/TBD	Various : Various	-	0.000		0.000		6.568		-		6.568	Continuing	Continuing	Continuing
Dynamically Composed RF Systems	C/TBD	Various : Various	-	0.000		0.000		13.212		-		13.212	Continuing	Continuing	Continuing
Multifunction RF (MFRF)	C/Various	Various : Various	-	9.702		4.801		0.000		-		0.000	0	14.503	0
Video-rate Synthetic Aperture Radar (ViSAR)	C/Various	Various : Various	-	16.586		10.965		0.000		-		0.000	0	27.551	0
Military Imaging and Surveillance Technology (MIST)	C/CPFF	TREX ENTERPRISES CORPORATION : CA	-	19.315	Mar 2015	7.835		0.000		-		0.000	0	27.150	0

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016

Appropriation/Budget Activity	**R-1 Program Element (Number/Name)**	**Project (Number/Name)**
0400 / 3	PE 0603767E / *SENSOR TECHNOLOGY*	SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Behavioral Learning for Adaptive Electronic Warfare (BLADE)	C/CPFF	LOCKHEED MARTIN CORPORATION : CA	-	5.148		0.000		0.000		-		0.000	0	5.148	0
		Subtotal	-	102.407		102.457		129.467		-		129.467	-	-	-

Support ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Government Support	MIPR	Various : Various	-	4.613		4.656		5.829		-		5.829	Continuing	Continuing	Continuing
		Subtotal	-	4.613		4.656		5.829		-		5.829	-	-	-

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Spatial, Temporal and Orientation Information for Contested Environments	C/Various	Various : Various	-	0.457		0.440		1.321		-		1.321	Continuing	Continuing	Continuing
Automatic Target Recognition (ATR) Technology	C/Various	Various : Various	-	1.635		0.000		0.000		-		0.000	0	1.635	0
Advanced Scanning Technology for Imaging Radars (ASTIR)	C/Various	Various : Various	-	0.000		0.000		0.350		-		0.350	Continuing	Continuing	Continuing
Small Satellite Sensors	C/Various	Various : Various	-	0.000		0.250		0.737		-		0.737	Continuing	Continuing	Continuing
Seeker Cost Transformation (SECTR)*	C/Various	Various : Various	-	0.000		0.969		0.741		-		0.741	Continuing	Continuing	Continuing
Multifunction RF (MFRF)	C/Various	Various : Various	-	0.437		0.533		0.000		-		0.000	0	0.970	0
Video-rate Synthetic Aperture Radar (ViSAR)	C/Various	Various : Various	-	0.000		0.831		0.000		-		0.000	0	0.831	0

Exhibit R-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016

Appropriation/Budget Activity	**R-1 Program Element (Number/Name)**	**Project (Number/Name)**
0400 / 3	PE 0603767E / *SENSOR TECHNOLOGY*	SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Military Imaging and Surveillance Technology (MIST)	SS/CPFF	LEIDOS,INC. : OH	-	0.000		0.440		0.000		-		0.000	0	0.440	0
		Subtotal	-	2.529		3.463		3.149		-		3.149	-	-	-

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Management Support	C/Various	Various : Various	-	5.766		5.820		7.287		-		7.287	Continuing	Continuing	Continuing
		Subtotal	-	5.766		5.820		7.287		-		7.287	-	-	-

	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	115.315	116.396	145.732	-	145.732	-	-	-

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Adaptive Radar Countermeasures																												
Develop Adaptive Radar Threat models for use in testing	■	■	■	■																								
Refine and integrate component algorithms for end-to-end system testing in simulation			■	■	■	■	■																					
Port software algorithms onto transition platform baseline EW systems			■																									
Demonstrate real-time prototype systems in hardware-in-the-loop laboratory environment				■	■	■	■	■																				
Complete realtime software and firmware implementation of major algortihm modules on transition plan							■	■	■																			
Spatial, Temporal and Orientation Information for Contested Environments (STOIC)																												
System concept design and analysis				■	■	■	■																					
Optical clock design and development				■	■	■																						
Optical clock lab verification and validation								■	■	■	■	■																
Navigation system demonstration												■																
Automatic Target Recognition (ATR) Technology																												
Design experiment and conduct data collection for baseline algorithm assessment			■																									
Design experiment and conduct data collection for adaptive algorithm assessment			■																									
Conduct baseline algorithm assessment						■																						
Evaluate algorithm adaptability									■																			

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency			**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*	

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Design experiment and conduct data collection for counter decoy assessment									■																			
Conduct Preliminary Design Review (PDR)										■																		
Evaluate algorithm ability to counter decoys											■																	
Advanced Scanning Technology for Imaging Radars (ASTIR)																												
Program Initiation					■																							
Mission application studies					■																							
Prototype development					■	■	■	■	■	■	■																	
Military application assessments												■																
Small Satellite Sensors																												
Program initiation					■																							
Preliminary design review						■	■																					
Final design review							■	■	■																			
Assembly, integration and testing									■	■	■	■																
Seeker Cost Transformation (SECTR)																												
Program Initiation					■																							
Hardware-in-the-loop system testing							■	■																				
Laboratory demonstrations										■	■																	
Critical design review											■	■																
Unbanded Spectrum operatIoNs (U-SPIN)																												
Program initiation									■																			
Initiate algorithmic study of techniques that achieve multiple spectrum operations									■																			
Dynamically Composed RF Systems																												
Program initiation									■																			

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Software development										■																		
Multifunction RF (MFRF)																												
Test platform modifications				■																								
Tower demonstration of prototype sensor								■																				
Prototype flight demonstrations								■																				
Video-rate Synthetic Aperture Radar (ViSAR)																												
Prototype high power amplifier development and testing	■	■	■																									
Integrate phenomenology data				■																								
Integrate components in gimbal in laboratory						■	■																					
Conduct flight tests								■																				
Military Imaging and Surveillance Technology (MIST)																												
Ground demonstrations of moderate range imaging system capability			■	■																								
Demonstrations of short-range imaging system								■																				
Mountain-to-ground demonstrations of moderate range imaging system								■																				
Behavioral Learning for Adaptive Electronic Warfare (BLADE)																												
Test & evaluate ground-based & airborne prototype system in an operationally relevant environment		■	■	■																								
Quantify minimum hardware requirements to execute the BLADE algorithms on transition platforms				■																								

Exhibit R-4, **RDT&E Schedule Profile:** PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

	FY 2015				FY 2016				FY 2017				FY 2018				FY 2019				FY 2020				FY 2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Conduct airborne demonstration against tactically relevant threats				■																								
Transition BLADE to US Army CERDEC I2WD				■																								

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Adaptive Radar Countermeasures				
Develop Adaptive Radar Threat models for use in testing	1	2015	4	2015
Refine and integrate component algorithms for end-to-end system testing in simulation	3	2015	3	2016
Port software algorithms onto transition platform baseline EW systems	3	2015	3	2015
Demonstrate real-time prototype systems in hardware-in-the-loop laboratory environment	4	2015	4	2016
Complete realtime software and firmware implementation of major algortihm modules on transition plan	3	2016	1	2017
Spatial, Temporal and Orientation Information for Contested Environments (STOIC)				
System concept design and analysis	4	2015	3	2016
Optical clock design and development	4	2015	2	2016
Optical clock lab verification and validation	4	2016	4	2017
Navigation system demonstration	4	2017	4	2017
Automatic Target Recognition (ATR) Technology				
Design experiment and conduct data collection for baseline algorithm assessment	3	2015	3	2015
Design experiment and conduct data collection for adaptive algorithm assessment	3	2015	3	2015
Conduct baseline algorithm assessment	2	2016	2	2016
Evaluate algorithm adaptability	1	2017	1	2017
Design experiment and conduct data collection for counter decoy assessment	1	2017	1	2017
Conduct Preliminary Design Review (PDR)	2	2017	2	2017
Evaluate algorithm ability to counter decoys	3	2017	3	2017
Advanced Scanning Technology for Imaging Radars (ASTIR)				

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Program Initiation	1	2016	1	2016
Mission application studies	1	2016	1	2016
Prototype development	1	2016	3	2017
Military application assessments	4	2017	4	2017
Small Satellite Sensors				
Program initiation	1	2016	1	2016
Preliminary design review	2	2016	3	2016
Final design review	3	2016	1	2017
Assembly, integration and testing	1	2017	4	2017
Seeker Cost Transformation (SECTR)				
Program Initiation	1	2016	1	2016
Hardware-in-the-loop system testing	3	2016	4	2016
Laboratory demonstrations	2	2017	3	2017
Critical design review	3	2017	4	2017
Unbanded Spectrum operatIoNs (U-SPIN)				
Program initiation	1	2017	1	2017
Initiate algorithmic study of techniques that achieve multiple spectrum operations	1	2017	1	2017
Dynamically Composed RF Systems				
Program initiation	1	2017	1	2017
Software development	2	2017	2	2017
Multifunction RF (MFRF)				
Test platform modifications	4	2015	4	2015
Tower demonstration of prototype sensor	4	2016	4	2016
Prototype flight demonstrations	4	2016	4	2016
Video-rate Synthetic Aperture Radar (ViSAR)				

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Prototype high power amplifier development and testing	1	2015	3	2015
Integrate phenomenology data	4	2015	4	2015
Integrate components in gimbal in laboratory	2	2016	3	2016
Conduct flight tests	4	2016	4	2016
Military Imaging and Surveillance Technology (MIST)				
Ground demonstrations of moderate range imaging system capability	3	2015	4	2015
Demonstrations of short-range imaging system	4	2016	4	2016
Mountain-to-ground demonstrations of moderate range imaging system	4	2016	4	2016
Behavioral Learning for Adaptive Electronic Warfare (BLADE)				
Test & evaluate ground-based & airborne prototype system in an operationally relevant environment	2	2015	4	2015
Quantify minimum hardware requirements to execute the BLADE algorithms on transition platforms	4	2015	4	2015
Conduct airborne demonstration against tactically relevant threats	4	2015	4	2015
Transition BLADE to US Army CERDEC I2WD	4	2015	4	2015

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency			Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
SEN-03: *EXPLOITATION SYSTEMS*	-	48.924	13.411	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

The Exploitation Systems project develops algorithms, software, and information processing systems to extract information from massive intelligence, surveillance, and reconnaissance (ISR) datasets. In particular, it develops 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 extends to open source information and issues such as trustworthiness and provenance. The resulting technology will enable 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 2015	FY 2016	FY 2017
Title: Insight	48.924	13.411	-

Description: Insight is developing the next generation multi-intelligence exploitation and analysis system. Insight provides new exploitation capabilities through an integrated, standards-based system that is designed for mission flexibility and cross-theater applicability. Insight will enable threat detection through combination and analysis of information from imaging and non-imaging sensors and other sources. The technical approach emphasizes 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 leverage both virtual and physical test bed environments. The virtual test bed enables evaluation of alternative sensor mixes and algorithms under extended operating conditions. The physical test bed enables live testing under realistic operational conditions using current and next generation sensing and processing systems. Insight technology development is coordinated with the following transition sponsors: Army Program Executive Office - Intelligence, Electronic Warfare & Sensors, United States Army Intelligence Center of Excellence, Project Manager Distributed Common Ground System - Army, Air Staff, National Air and Space Intelligence Center, and Air Force Research Laboratory. Insight provides a unified architecture for plug-and-play ISR with extensibility to all Services and Combatant Commands.

FY 2015 Accomplishments:
- Completed initial software deliveries and transferred fusion and analytic technology to the Army and Air Force.
- Adapted capabilities to emerging operational environments, including integration of additional non-traditional sensors and information sources.
- Tested and matured advanced fusion and analytic technologies in live and virtual environments.
- Executed a live field test in coordination with a military training rotation to demonstrate improvements and maturity of system capabilities in a dynamic operational environment.
- Developed a new and advanced data model compatible with existing system data models.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017
- Delivered refined, advanced and integrated capabilities to transition partner programs of record that address key performance parameters and are aligned with their software release cycles. ***FY 2016 Plans:*** - Test advanced fusion and analytic technologies, and demonstrate improvements and maturity of multi-intelligence exploitation capabilities. - Tailor final component and system level capabilities to specific transition partner objectives. - Deliver final integrated capabilities that address key performance parameters required by transition partner programs of record for insertion into software baselines. - Prepare and finalize software packages and documentation for transition to Services.			
Accomplishments/Planned Programs Subtotals	48.924	13.411	-

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-3, RDT&E Project Cost Analysis: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-03 / *EXPLOITATION SYSTEMS*

Product Development ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Insight	C/CPFF	BAE : MA	-	27.008	Oct 2014	0.000		0.000		-		0.000	0	27.008	0
Insight	C/Various	Various : Various	-	15.014		11.283		0.000		-		0.000	0	26.297	0
		Subtotal	-	42.022		11.283		0.000		-		0.000	0.000	53.305	0.000

Support ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Insight	MIPR	Various : Various	-	1.956		0.536		0.000		-		0.000	0	2.492	0
		Subtotal	-	1.956		0.536		0.000		-		0.000	0.000	2.492	0.000

Test and Evaluation ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Insight	C/Various	Various : Various	-	2.500		0.921		0.000		-		0.000	0	3.421	0
		Subtotal	-	2.500		0.921		0.000		-		0.000	0.000	3.421	0.000

Management Services ($ in Millions)

Cost Category Item	Contract Method & Type	Performing Activity & Location	Prior Years	FY 2015 Cost	FY 2015 Award Date	FY 2016 Cost	FY 2016 Award Date	FY 2017 Base Cost	FY 2017 Base Award Date	FY 2017 OCO Cost	FY 2017 OCO Award Date	FY 2017 Total Cost	Cost To Complete	Total Cost	Target Value of Contract
Insight	C/CPFF	Various : Various	-	2.446		0.671		0.000		-		0.000	0	3.117	0
		Subtotal	-	2.446		0.671		0.000		-		0.000	0.000	3.117	0.000

	Prior Years	FY 2015		FY 2016		FY 2017 Base		FY 2017 OCO		FY 2017 Total	Cost To Complete	Total Cost	Target Value of Contract
Project Cost Totals	-	48.924		13.411		0.000		-		0.000	0.000	62.335	0.000

Remarks

Exhibit R-4, RDT&E Schedule Profile: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-03 / *EXPLOITATION SYSTEMS*

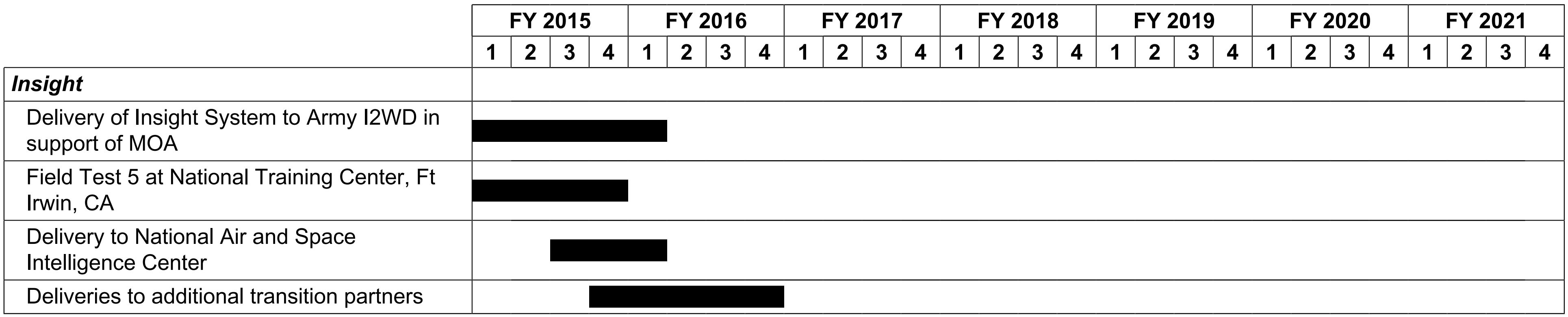

Exhibit R-4A, RDT&E Schedule Details: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-03 / *EXPLOITATION SYSTEMS*

Schedule Details

	Start		End	
Events by Sub Project	**Quarter**	**Year**	**Quarter**	**Year**
Insight				
Delivery of Insight System to Army I2WD in support of MOA	1	2015	1	2016
Field Test 5 at National Training Center, Ft Irwin, CA	1	2015	4	2015
Delivery to National Air and Space Intelligence Center	3	2015	1	2016
Deliveries to additional transition partners	4	2015	4	2016

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
SEN-06: *SENSOR TECHNOLOGY*	-	87.400	92.199	76.529	-	76.529	46.800	17.875	5.000	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 2015	FY 2016	FY 2017
Title: Classified DARPA Program ***Description:*** This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2015 Accomplishments:*** Details will be provided under separate cover. ***FY 2016 Plans:*** Details will be provided under separate cover. ***FY 2017 Plans:*** Details will be provided under separate cover.	87.400	92.199	76.529
Accomplishments/Planned Programs Subtotals	87.400	92.199	76.529

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Details will be provided under separate cover.

Exhibit R-2, **RDT&E Budget Item Justification:** PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	0.000	0.000	69.244	-	69.244	71.293	72.930	73.134	72.995	-	-
MST-01: *MISSION SUPPORT*	-	0.000	0.000	69.244	-	69.244	71.293	72.930	73.134	72.995	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

This program element is budgeted in the Management Support Budget Activity because 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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	0.000	0.000	0.000	-	0.000
Current President's Budget	0.000	0.000	69.244	-	69.244
Total Adjustments	0.000	0.000	69.244	-	69.244
• 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	-	-	69.244	-	69.244

Change Summary Explanation

FY 2015: N/A

FY 2016: N/A

FY 2017: Increase reflects Departmental implementation of congressional direction.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Mission Support ***Description:*** Mission Support ***FY 2017 Plans:***	-	-	69.244

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
- 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. - Fund CFO Act compliance costs.			
Accomplishments/Planned Programs Subtotals	-	-	69.244

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	85.266	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
SB-01: *SMALL BUSINESS INNOVATION RESEARCH*	-	85.266	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: 112-81 (National Defense Authorization Act) and Small Business Technology Transfer Program Reauthorization Act, 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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	0.000	0.000	0.000	-	0.000
Current President's Budget	85.266	0.000	0.000	-	0.000
Total Adjustments	85.266	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	85.266	0.000			

Change Summary Explanation

FY 2015: Increase reflects the SBIR/STTR transfer.
FY 2016: N/A
FY 2017: N/A

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Small Business Innovation Research ***Description:*** The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are	85.266	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
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 2015	FY 2016	FY 2017
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. ***FY 2015 Accomplishments:*** - The DARPA SBIR and STTR were executed within OSD guidelines.			
Accomplishments/Planned Programs Subtotals	85.266	-	-

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

Not applicable.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	71.362	71.571	4.759	-	4.759	4.835	4.449	4.300	4.389	-	-
MH-01: *MANAGEMENT HQ - R&D*	-	71.362	71.571	4.759	-	4.759	4.835	4.449	4.300	4.389	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

This program element is budgeted in the Management Support Budget Activity because it provides funding for the administrative support costs of the Defense Advanced Research Projects Agency. In FY 2015 and 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 costs. Mission support costs are reflected in PE 0605001E, Project MST-01.

B. Program Change Summary ($ in Millions)

	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	71.362	71.571	73.539	-	73.539
Current President's Budget	71.362	71.571	4.759	-	4.759
Total Adjustments	0.000	0.000	-68.780	-	-68.780
• 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	-	-	-68.780	-	-68.780

Change Summary Explanation

FY 2015: N/A

FY 2016: N/A

FY 2017: Decrease reflects Departmental implementation of congressional direction.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: Management Headquarters	71.362	71.571	4.759

Exhibit R-2, **RDT&E Budget Item Justification:** PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
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 2015**	**FY 2016**	**FY 2017**
Description: Management Headquarters ***FY 2015 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 2016 Plans:*** - Fund 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. - Fund CFO Act compliance costs. ***FY 2017 Plans:*** - Fund management headquarters civilian salaries, benefits, and travel costs.			
Accomplishments/Planned Programs Subtotals	71.362	71.571	4.759

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.