Department of Defense
Fiscal Year (FY) 2016 President's Budget Submission

February 2015

Defense Advanced Research Projects Agency

Defense Wide Justification Book Volume 1 of 1

Research, Development, Test & Evaluation, Defense-Wide

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Department of Defense
FY 2016 President's Budget
Exhibit R-1 FY 2016 President's Budget
Total Obligational Authority
(Dollars in Thousands)

07 Jan 2015

Appropriation	FY 2014 (Base & OCO)	FY 2015 Base Enacted	FY 2015 OCO Enacted	FY 2015 Total Enacted	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Research, Development, Test & Eval, DW	2,752,656	2,870,932	45,000	2,915,932	2,972,693		2,972,693
Total Research, Development, Test & Evaluation	2,752,656	2,870,932	45,000	2,915,932	2,972,693		2,972,693

Department of Defense
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07 Jan 2015

Summary Recap of Budget Activities	FY 2014 (Base & OCO)	FY 2015 Base Enacted	FY 2015 OCO Enacted	FY 2015 Total Enacted	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Basic Research	341,350	392,903		392,903	389,663		389,663
Applied Research	1,133,007	1,102,303	45,000	1,147,303	1,209,380		1,209,380
Advanced Technology Development	1,126,615	1,304,364		1,304,364	1,302,079		1,302,079
Management Support	151,684	71,362		71,362	71,571		71,571
Total Research, Development, Test & Evaluation	2,752,656	2,870,932	45,000	2,915,932	2,972,693		2,972,693

Summary Recap of FYDP Programs	FY 2014 (Base & OCO)	FY 2015 Base Enacted	FY 2015 OCO Enacted	FY 2015 Total Enacted	FY 2016 Base	FY 2016 OCO	FY 2016 Total
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R-1C1: FY 2016 President's Budget (Published Version of PB Position), as of January 7, 2015 at 09:29:53

Defense-Wide
FY 2016 President's Budget
Exhibit R-1 FY 2016 President's Budget
Total Obligational Authority
(Dollars in Thousands)

07 Jan 2015

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

Line No	Program Element Number	Item	Act	FY 2014 (Base & OCO)	FY 2015 Base Enacted	FY 2015 OCO Enacted	FY 2015 Total Enacted	FY 2016 Base	FY 2016 OCO	FY 2016 Total	Sec
2	0601101E	Defense Research Sciences	01	293,284	332,146		332,146	333,119		333,119	U
4	0601117E	Basic Operational Medical Research Science	01	48,066	60,757		60,757	56,544		56,544	U
		Basic Research		341,350	392,903		392,903	389,663		389,663	
9	0602115E	Biomedical Technology	02	121,152	114,790	45,000	159,790	114,262		114,262	U
12	0602303E	Information & Communications Technology	02	370,643	324,407		324,407	356,358		356,358	U
13	0602304E	Cognitive Computing Systems	02	15,847							U
14	0602383E	Biological Warfare Defense	02	25,648	43,780		43,780	29,265		29,265	U
18	0602702E	Tactical Technology	02	218,482	299,734		299,734	314,582		314,582	U
19	0602715E	Materials and Biological Technology	02	158,948	150,389		150,389	220,115		220,115	U
20	0602716E	Electronics Technology	02	222,287	169,203		169,203	174,798		174,798	U
		Applied Research		1,133,007	1,102,303	45,000	1,147,303	1,209,380		1,209,380	
38	0603286E	Advanced Aerospace Systems	03	146,789	129,723		129,723	185,043		185,043	U
39	0603287E	Space Programs and Technology	03	127,948	179,883		179,883	126,692		126,692	U
57	0603739E	Advanced Electronics Technologies	03	92,001	92,246		92,246	79,021		79,021	U
58	0603760E	Command, Control and Communications Systems	03	229,510	239,265		239,265	201,335		201,335	U
59	0603766E	Network-Centric Warfare Technology	03	261,613	360,426		360,426	452,861		452,861	U
60	0603767E	Sensor Technology	03	268,754	302,821		302,821	257,127		257,127	U
		Advanced Technology Development		1,126,615	1,304,364		1,304,364	1,302,079		1,302,079	
154	0605502E	Small Business Innovative Research	06	80,025							U

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163	0605898E	Management HQ - R&D	06	71,659	71,362		71,362	71,571		71,571	U
		Management Support		151,684	71,362		71,362	71,571		71,571	
		Total Research, Development, Test & Eval, DW		2,752,656	2,870,932	45,000	2,915,932	2,972,693		2,972,693	

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19	0602715E	Materials and Biological Technology	02	158,948	150,389		150,389	220,115		220,115	U
20	0602716E	Electronics Technology	02	222,287	169,203		169,203	174,798		174,798	U
		Applied Research		1,133,007	1,102,303	45,000	1,147,303	1,209,380		1,209,380	
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Budget Activity 02: Applied Research
Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Budget Activity 03: Advanced Technology Development (ATD)
Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Budget Activity 06: RDT&E Management Support
Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

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Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	293.284	332.146	333.119	-	333.119	328.362	339.350	343.736	355.434	-	-
BLS-01: *BIO/INFO/MICRO SCIENCES*	-	20.355	15.036	6.127	-	6.127	-	-	-	-	-	-
CCS-02: *MATH AND COMPUTER SCIENCES*	-	88.325	118.743	132.336	-	132.336	140.283	152.116	162.783	173.036	-	-
CYS-01: *CYBER SCIENCES*	-	23.720	58.462	53.774	-	53.774	45.000	47.219	27.000	10.000	-	-
ES-01: *ELECTRONIC SCIENCES*	-	35.969	37.411	40.401	-	40.401	44.578	36.951	39.796	44.883	-	-
MS-01: *MATERIALS SCIENCES*	-	93.010	73.077	70.368	-	70.368	69.966	72.233	73.780	85.138	-	-
TRS-01: *TRANSFORMATIVE SCIENCES*	-	31.905	29.417	30.113	-	30.113	28.535	30.831	40.377	42.377	-	-

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 2016 Defense Advanced Research Projects Agency	Date: February 2015
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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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	315.033	312.146	322.923	-	322.923
Current President's Budget	293.284	332.146	333.119	-	333.119
Total Adjustments	-21.749	20.000	10.196	-	10.196
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	20.000			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-12.436	-			
• SBIR/STTR Transfer	-9.313	-			
• TotalOtherAdjustments	-	-	10.196	-	10.196

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2014	FY 2015
Project: CCS-02: *MATH AND COMPUTER SCIENCES*		
Congressional Add: *Basic Research Congressional Add*	-	5.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014**	**FY 2015**
Congressional Add Subtotals for Project: CCS-02	-	5.000
Project: CYS-01: *CYBER SCIENCES*		
Congressional Add: *Basic Research Congressional Add*	-	5.000
Congressional Add Subtotals for Project: CYS-01	-	5.000
Project: ES-01: *ELECTRONIC SCIENCES*		
Congressional Add: *Basic Research Congressional Add*	-	5.000
Congressional Add Subtotals for Project: ES-01	-	5.000
Project: MS-01: *MATERIALS SCIENCES*		
Congressional Add: *Basic Research Congressional Add*	-	5.000
Congressional Add Subtotals for Project: MS-01	-	5.000
Congressional Add Totals for all Projects	-	20.000

Change Summary Explanation

FY 2014: Decrease reflects below threshold and omnibus reprogrammings and the SBIR/STTR transfer.
FY 2015: Increase reflects congressional adds.
FY 2016: Increase reflects expanded focus in Cyber Sciences.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
BLS-01: *BIO/INFO/MICRO SCIENCES*	-	20.355	15.036	6.127	-	6.127	-	-	-	-	-	-

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 rapid responses to engineered biological warfare agents, radically new biomolecular computers, 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 2014	FY 2015	FY 2016
Title: Quantitative Models of the Brain	9.150	10.636	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., TBI, 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 2014 Accomplishments:*** - Demonstrated hyperspectral imaging using 100x fewer measurements than reconstructed pixels. - Explored the application of compressive sensing concepts to alternate sensing modalities such as x-ray imaging. - Investigated the potential gains available from compressive sensing within multiple video applications.			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Leveraged advances in neuroscience and neurological measurements to develop predictive, quantitative models of memory, learning, and neuro-physiologic recovery. ***FY 2015 Plans:*** - Quantify spatio-temporal patterns of neurochemical activity underlying memory formation. - Extend model and brain regions to account for hierarchical organization of memories (procedural, declarative/episodic). - Demonstrate model prediction of knowledge and skill-based memory encoding. - Develop model of memory encoding using non-invasively recorded neural signals. ***FY 2016 Plans:*** - Build a hippocampal-neocortical model of stimulation-based memory enhancement. - Develop sparse multiple input/multiple output nonlinear dynamical modeling methodology for real-time application to electrophysiological recordings. - 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.			
Title: Bio Interfaces ***Description:*** The Bio Interfaces program supports scientific study and experimentation, emphasizing the interfaces between biology and the physical and mathematical/computer sciences. This unique interaction will develop new mathematical and experimental tools for understanding biology in a way that will allow 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 will also explore the fundamental nature of time in biology and medicine. This will include 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 2014 Accomplishments:*** - Experimentally validated canonical spatio-temporal episequences, and developed a minimal dataset for accurate predictions of temporal processes such as cell cycle progression, metabolic cycles, and lifespan. - Refined predictive algorithms of the progression of biological time. - Developed and tested the predictive model or algorithm against a blind panel to predict doubling time, cell cycle progression, metabolism and lifespan metrics. ***FY 2015 Plans:*** - Investigate alternative strategies for treating disease by targeting clocking systems that drive temporal processes such as cell cycle progression and metabolic cycles.	9.705	4.400	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Test the ability of predictive algorithms of biological time to enable an economical and easily administered test to assess and predict human circadian phase from blood. - Leverage temporally collected data to test the impact of time on drug efficacy. - Discover and test novel compounds that target oscillatory networks to modulate neurodegenerative disease in an animal model.			
Title: Physics in Biology ***Description:*** Understanding the fundamental physical phenomena that underlie biological processes and functions can provide new insights and lead to unique opportunities for exploiting such phenomena. The Physics in Biology thrust explored the role and impact of quantum effects in biological processes and systems. This included exploiting manifestly quantum mechanical effects that exist in biological systems at room temperature to develop a revolutionary new class of robust, compact, high sensitivity and high selectivity sensors. The quantum phenomena uncovered was demonstrated to control the attraction of insects to humans with the potential to significantly reduce insect bites and thus the transmission of parasitic, bacterial or viral pathogens. ***FY 2014 Accomplishments:*** - Demonstrated prototype quantum biological sensors and measured against equivalent state-of-the-art sensors in order to quantify the increase in sensitivity, selectivity and other performance metrics. - Explored quantum physics-based mechanisms of mosquito bio-sensing related to mosquito attraction to humans for novel, vector-born disease protection against diseases such as malaria or dengue fever.	1.500	-	-
Accomplishments/Planned Programs Subtotals	20.355	15.036	6.127

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 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
CCS-02: *MATH AND COMPUTER SCIENCES*	-	88.325	118.743	132.336	-	132.336	140.283	152.116	162.783	173.036	-	-

A. Mission Description and Budget Item Justification

This project supports scientific study and experimentation on new computational 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; 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. Promising techniques will transition to both technology development and system-level projects.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Big Mechanism	8.090	16.000	23.000
Description: The Big Mechanism program will create 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 in critical areas such as cancer modeling, systems biology, epidemiology, cyber attribution, open-source intelligence, and economic indications and warning. ***FY 2014 Accomplishments:*** - Formulated initial causal-model-based automated computational intelligence techniques applicable to cancer modeling. - Developed novel information-extraction technologies suitable for extracting causal fragments from scientific literature.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Developed initial algorithms for assembling causal fragments into larger models. ***FY 2015 Plans:*** - Develop model management techniques for storing, manipulating, and reasoning about tens of thousands of alternative causal models. - Develop techniques to generate plausible causal hypotheses that can be tested in the lab. - Develop tools for operator drill-down, ambiguity clarification, and inconsistency reconciliation. - Develop techniques for automatic query generation given partial/incomplete knowledge/models. ***FY 2016 Plans:*** - Demonstrate prototype technologies in production mode by identifying drug targets and drugs for one or more specific classes of cancer. - 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. - Formulate statistical approaches for uncovering causal relationships in numerical data/time series and categorical data/symbol sequences. - Develop and implement scalable algorithms that reveal causality networks in large, complex, heterogeneous datasets.			
Title: Unconventional Processing of Signals for Intelligent Data Exploitation (UPSIDE) ***Description:*** The Unconventional Processing of Signals for Intelligent Data Exploitation (UPSIDE) program will address the open problems facing real-time Intelligence, Surveillance and Reconnaissance (ISR) systems and other power-constrained data-intensive applications. The objective of the UPSIDE program is to create a high-level, non-Boolean computational model and map it directly to the unique functional properties of new emerging devices to achieve significant increases in power efficiency and performance. The UPSIDE program will create a new generation of computing structures that will, in turn, enable revolutionary advances in ISR processing, particularly for DoD applications of embedded, real-time sensor data analysis. Boolean data representations are inherently power-inefficient for many datasets, particularly those produced by noisy analog real-time sensors. The UPSIDE program will establish an unconventional, non-Boolean, computing paradigm to enable new and needed capabilities in the area of sensor data analysis. UPSIDE intends to implement this new computing paradigm in the form of a specialized hardware component termed the inference module (IM). An IM is a computational abstraction, which performs a sophisticated pattern match that maps very efficiently to analog complementary metal-oxide semiconductor (CMOS) circuits and emerging devices. An IM can leverage the physics of an emerging device to compute a pattern match directly. The IM will be first developed through simulation, and then implemented using mixed-signal CMOS technology, as well as using state of the art emerging (non-CMOS) devices. Throughout the program, the inference module will be benchmarked using a DoD-relevant image processing pipeline, to verify gains in both	15.000	21.500	18.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016

computing throughput and power efficiency. The result will be computing infrastructures and functional implementations that demonstrate three orders of magnitude improvement in processing speed and four orders of magnitude improvement in power efficiency. These gains will constitute a disruptive new level of embedded computational efficiency for future real-time sensor systems.

FY 2014 Accomplishments:
- Created conventional image processing pipeline simulation for tracking moving objects in surveillance video for the baseline comparison of UPSIDE image processing metrics.
- Demonstrated that new image processing pipelines using UPSIDE IM exceed goals for equivalent accuracy in object tracking.
- Performed system analysis showing that UPSIDE image processing pipeline can achieve power and performance goals of the program.
- Completed architectural design of a mixed-signal complementary metal-oxide semiconductor (CMOS) chip-based inference module architecture which will be used in the image processing pipeline.
- Fabricated and demonstrated first mixed-signal chips for performing inference module processing for object tracking.
- Measured emerging device specifications for use in simulations showing power and performance of an emerging-device-based inference module in an image processing pipeline.
- Performed initial fabrications of the emerging device(s).
- Began design and development of CMOS support chip containing external digital circuitry required for power, communication and control of the emerging device circuits.

FY 2015 Plans:
- Simulate the selected image processing pipeline utilizing the previously developed inference methodology.
- Develop mixed-signal CMOS based image processing pipeline simulation and validate the simulation of the image processing pipeline using real-time, high-definition video streams.
- Design and fabricate mixed-signal CMOS chip implementation of inference module.
- Fabricate and demonstrate simple circuits based on emerging devices for future inference module development.

FY 2016 Plans:
- Implement full image processing pipeline system in software and provide to a distributed computing environment for maximum digital performance.
- Deliver an inference module based system test bed using the mixed-signal CMOS chip for executing the image processing pipeline with an evaluation in terms of the power, performance and accuracy of the system.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Evaluate the image processing pipeline using the emerging devices showing 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: 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 speculative 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 2014 Accomplishments:*** - Exercised the second year options for successful FY 2013 participants to continue research focused on new concepts for microsystem technologies and defense sciences. - Awarded 28 FY 2014 grants for new two-year research efforts across the topic areas. - Identified the top FY 2013 participants as candidates for selection as a Director's Fellow. During this additional year of funding, researchers further refined their technology to align to DoD needs. - Established approaches to bring appropriate technologies developed through YFA to bear on relevant DoD problems. - Provided awardees mentorship by program managers and engagement with DARPA to encourage future work that focuses on DoD needs. ***FY 2015 Plans:*** - Award Director's Fellowships from top FY 2013 participants. During this additional year of funding researchers will refine their technology further and align to DoD needs. - Exercise second year options for FY 2014 participants to continue research focused on new concepts for microsystem technologies, biological technologies and defense sciences. - Award FY 2015 grants for new two-year research efforts across the topic areas. - Establish approaches to bring appropriate technologies developed through YFA to bear on relevant DoD problems.	15.306	16.501	17.248

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Provide awardees mentorship by program managers and engagement with DARPA to encourage future work that focuses on DoD needs. ***FY 2016 Plans:*** - Award Director's Fellowships for researchers to refine their technology further and align to DoD needs. - Exercise options for FY 2015 participants to continue research focused on new concepts for microsystem technologies, biological technologies, and defense sciences. - Award FY 2016 grants for new two-year research efforts across the topic areas. - Establish approaches to bring appropriate technologies developed through YFA to bear on relevant DoD problems. - Provide awardees mentorship by program managers and engagement with DARPA to encourage future work that focuses on DoD needs.			
Title: Probabilistic Programming for Advancing Machine Learning (PPAML) ***Description:*** The Probabilistic Programming for Advancing Machine Learning (PPAML) program will create 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, will make experts more productive, and will enable the creation of new tactical applications that are inconceivable given today's tools. The key enabling technology is a new programming paradigm called probabilistic programming that facilitates the management of uncertain information. In this approach, developers will use the power of a modern (probabilistic) programming language to quickly build a generative model of the phenomenon of interest as well as queries of interest, which a compiler will convert into an efficient application. PPAML technologies will be designed for application to a wide range of military domains including ISR exploitation, robotic and autonomous system navigation and control, and medical diagnostics. ***FY 2014 Accomplishments:*** - Designed and built the front end of a probabilistic programming system that enables users at a range of skill levels to construct concise, useful models. - Designed and built the back end of a probabilistic programming system that takes as input expressive models written in a probabilistic programming language, queries, and prior data and produces as output an efficient implementation with predictable performance. - Identified and developed three challenge problems from various military domains (quad-rotor sensor fusion, autonomous swarm tracking, and wide-area motion imagery tracking), including collecting and making available sample data of appropriate size. ***FY 2015 Plans:*** - Identify and develop two additional challenge problems from various military domains with increasing levels of complexity and larger data sets.	10.221	14.021	16.088

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Evaluate performance of each probabilistic programming system on each challenge problem. - Extend the front end of a probabilistic programming system with additional functionality, including profilers, debuggers, and model verification/checking tools. - Extend the back end of a probabilistic programming system with additional functionality, such as determining which solver or set of solvers is most appropriate for a given input, improving efficiency of solvers, and compiling inference engines to a range of different hardware targets. ***FY 2016 Plans:*** - Identify and develop two additional challenge problems from different military domains with increasing levels of complexity and larger data sets. - Evaluate the performance of each probabilistic programming system on all existing challenge problems both in terms of the quality of the answers and the levels of resources required. - Continue to extend the front end of a probabilistic programming system with more advanced functionality, including profilers, debuggers, and model verification/checking tools. - Continue to extend the back end of a probabilistic programming system with more advanced functionality, such as determining which solver or set of solvers is most appropriate for a given input, improving efficiency of solvers, and compiling inference engines to a range of different hardware targets. - Evaluate the effectiveness of the developed systems by running a summer school in collaboration with potential transition partners.			
Title: Mining and Understanding Software Enclaves (MUSE) ***Description:*** The Mining and Understanding Software Enclaves (MUSE) program will develop 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 2014 Accomplishments:*** - Assembled, cataloged, and developed ontologies for an initial multi-lingual corpus of open source software to serve as target data for software analytics.	4.500	8.000	12.100

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Developed a number of database schema designs to persistently record program analysis outputs, responsive to the queries necessary to drive synthesis and repair activities. ***FY 2015 Plans:*** - Conceive, design, and implement 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. - Design application programming interfaces and implementations of a mining engine that provides support for the efficient injection, querying, inspection, and optimization of the underlying database that is used as the output of program analyses, and the input to software analytics. - Examine repair and synthesis strategies to automatically discover commonalities and fix anomalies in input programs based on mining semantic patterns in the corpus. - Develop deductive database formulations for logical inference, multi-view query systems for machine learning analytics, and probabilistic query engines that collectively enable the implementation of different analytic back ends. - Extend the corpus with richer semantic ontologies and metadata support to deal with diverse language frameworks, environments, and systems at scale. ***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 that automatically construct implementations of complex protocols from discovered specifications. - Identify key challenge problems in automated repair and security analysis, along with novel solutions that directly exploit the latent semantic content in the database.			
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	5.213	4.903	2.900

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 2014 Accomplishments:*** - Developed mathematical models and demonstrated mechanistic methods on use cases in DoD-relevant scenarios including brain science, decision support tools for health and disease prevention and prediction, massive streaming networks, and gene networks. - Investigated and developed probabilistic graph models, statistical measures, and statistical sampling procedures for various graph models. ***FY 2015 Plans:*** - Create a suite of systematic network analysis tools that can be applied to static and dynamic network structures and complex use cases. - Develop 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: Knowledge Representation ***Description:*** The Knowledge Representation thrust, an outgrowth from the Mathematics of Sensing, Exploitation and Evaluation area, 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 Plans:***	-	12.000	13.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Develop an initial mathematical knowledge framework for representing diverse data types and existing domain knowledge in a domain-agnostic form. - Establish 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. - Design appropriate tools for ingesting and registering scientific data into a common mathematical representation and demonstrate the tools for example, datasets. ***FY 2016 Plans:*** - Demonstrate data input and information extraction within the 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.			
Title: Communicating With Computers (CWC)* ***Description:*** *Formerly Human and Computer Symbiosis (HCS) The Communicating With Computers (CWC) program will advance 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 communication is the process by which an idea in one person's mind becomes an idea in another's. 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; link language to this perceptual encoding; and learn the skills of communication. 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: these 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; program evaluations will include tests of this sort of transfer. CWC advances will impact military application areas such as robotics and command and control. ***FY 2015 Plans:*** - Formulate 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. - Create a semantic framework for gesture, facial expression and other communicative modalities. - Explore methods for determining whether transmitted communications have been successfully received and, if not, what additional communications are most likely to result in success. ***FY 2016 Plans:***	-	8.118	10.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Implement representations for the physical world and develop connectors to large-scale knowledge bases to enable visual-language synergies. - 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 to potentially missing information.			
Title: Building Resource Adaptive Software from Specifications (BRASS) ***Description:*** The Building Resource-Adaptive Software from Specifications (BRASS) program seeks to build 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. Currently, the processes by which applications adapt to environment change via corrective patches 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 break. This restructuring is optimized to trade off execution fidelity and functionality for continued operation. BRASS will create tools to automatically discover and monitor resource changes, build new analyses to infer deep resource-based specifications, and implement compiler and runtime transformations that can efficiently adapt to resource changes. BRASS will expand on research encountered in the Mining and Understanding Software Enclaves program. ***FY 2015 Plans:*** - Formulate specification techniques that allow the high-level expression of resource constraints inferred from a diverse set of sources including test suites, bug databases, and program analyses. ***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.	-	2.500	9.500
Title: Quantifying Uncertainty in Physical Systems	-	6.200	8.550

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Description: The Quantifying Uncertainty in Physical Systems thrust, an outgrowth of the Mathematics of Sensing, Exploitation and Evaluation area, 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 predicting rare events; and new methods for decision making, control, and design under uncertain conditions. ***FY 2015 Plans:*** - Initiate development of new dimensional reduction and surrogate model methods with theoretical error bounds for rigorous uncertainty of large-scale, coupled systems. - Initiate development of a new theoretical framework for optimization in the presence of high dimensional uncertain parameters. - Initiate development of new model-form 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. - Implement algorithms for estimation of quantities in physical systems in the presence of uncertainty on emerging high-performance computing platforms. - Derive proofs and theoretical treatment of rare event detection algorithms within risk-based optimization framework.			
Title: Complexity Management Hardware* ***Description:*** *Formerly Cortical Processor The battlefield of the future will certainly have more data generators and sensors that define the information required to execute appropriately. With networked sensors, the variety and complexity of the information streams will be even further extended. This project will explore 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 which need to account for 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	-	4.000	1.450

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 will look at various algorithms to explore the ability to use context to adapt to new information. This will start with exploration of the ability to automatically recognize information within streams of data, and then to extract context from the dataset. This will extend to exploiting that context to further refine the processing of an orthogonal data set. Applied research for the program is budgeted in PE 0602303E, Project IT-02. ***FY 2015 Plans:*** - Develop a hierarchical temporal memory (HTM) algorithm including new data representations, low precision and ability to adapt and scale. - Perform benchmark calculations on data streams showing accurate pattern recognition with minimal training times in a variety of applications. ***FY 2016 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: Engage ***Description:*** The Engage program developed on-line approaches for complex problem solving in real-world settings by analyzing and adapting performance across large numbers of users. Using unconventional mechanisms and incentives, Engage created an on-line environment for data-driven, interactive, multidisciplinary collaboration among experts and non-experts to address heretofore insolvable challenge problems. This big-data analysis approach identified optimum training strategies, resulting in the development of software that is highly individualized to the user. Engage also addressed the difficult problem of assessing performance in the virtual domain to predict performance in the real world and drive the creation of more effective on-line education and training. Engage technology development was coordinated with the Department of Defense Educational Activity (DoDEA). ***FY 2014 Accomplishments:*** - Developed and released Engage-based software for training additional topics. - Developed novel assessment models for adapting educational technologies to individual users. - Created a collection of research-based technologies that align with national educational standards.	11.815	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Executed an MOU and pilot with DoDEA to incorporate one or more ENGAGE games into DoDEA curriculum. - ENGAGE robotics games were used in over 16K classrooms by over 276K students. - ENGAGE games have been played by over 5 million players (projected to be 13 million by June 2015). - Developed design and simulation tools that allow students and instructors to determine the operation of a complex electro-mechanical system. - Demonstrated the linking between design and prototyping tools that will allow for in-field manufacturing of failed components. - Demonstrated the linking of instructional design and simulation tools with rapid prototyping machines to allow for the troubleshooting and repair of failed components in electro-mechanical systems.			
Title: Strategic Social Interaction Modules (SSIM) ***Description:*** The Strategic Social Interaction Modules (SSIM) program improved military training to include the social interaction skills and abilities warfighters need for successful engagement with local populations. In the current and likely future operational environment, it is imperative to develop rapport with local leaders and civilians as their cooperation and consent will be necessary for successful operations. SSIM emphasized the foundational social skills necessary to achieve cultural understanding in any social setting and the skills necessary for successful interactions across different social groups. These core skills do not require soldiers to have knowledge of a specific culture prior to contact but emphasizes skills for orienting toward and discovering patterns of meaningful social behavior. SSIM developed the requisite training technology, including advanced gaming/simulation techniques, that incorporate new methods for practicing social agility in social encounters, as well as how to discover and adapt to unfamiliar culturally-specific conduct, manners, and practices. SSIM enhanced military effectiveness by enabling close collaborative relationships with local peoples and leaders. ***FY 2014 Accomplishments:*** - Refined the curriculum for SSIM-oriented training based on findings regarding effective social interaction. - Completed the assessment of the effectiveness of SSIM-training to determine direct and indirect effects. - Transitioned SSIM-based training and training simulator to transition partners. - Completed field-testing of prototypes and deployed new training technologies.	10.777	-	-
Title: Mathematics of Sensing, Exploitation and Evaluation (MSEE) ***Description:*** The Mathematics of Sensing, Exploitation and Evaluation (MSEE) program sought to create a comprehensive mathematical theory of information processing, strategy formulation and decision determination. Such a theory incorporates techniques from diverse mathematical disciplines such as Stochastic Process Theory, Harmonic Analysis, Formal Languages and Theoretical Computer Science to construct a common framework wherein the quantitative value of data acquisition may be assessed relative to dynamically-varying context. In addition, the structure accommodates the notion that data acquisition and information processing are coupled, requiring some degree of feedback and control, while simultaneously admitting the	4.853	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
possibility of different logics, such as those that allow for incomplete and time-varying states of knowledge. The result of this effort produced advances in fundamental domains of mathematics with the potential to reshape current DoD approaches to managing the battlespace and supervisory controls. ***FY 2014 Accomplishments:*** - Implemented multiple-modality solutions that demonstrated the effectiveness of a unified approach to sensing. - Created an advanced evaluation test-bed that enabled probative, quantitative assessment of a system's ability to understand scene semantics. - Demonstrated enhanced anomaly detection under varying operating conditions, including production of a single (unified) semantic representation of a scene in the presence of coincident sensor data coming from multiple modalities, some of which comprised electro-optical/IR.			
Title: Computer Science Study Group (CSSG) ***Description:*** The Computer Science Study Group (CSSG) program supported emerging ideas from the computer science academic community to address the DoD's need for innovative computer and information technologies; introduced a generation of junior researchers to the needs and priorities of the DoD; and enabled the transition of those ideas and applications by promoting joint university, industry, and government projects. The CSSG project formalized and focused this research for efficiency and greater effectiveness. ***FY 2014 Accomplishments:*** - Transitioned successful research outcomes from Classes 2010-2011. - Conducted CSSG Continuing Research Series Text and Video Analytics Workshop at Army Research Laboratory. - Conducted a National Security Innovation Workshop at the Institute for Defense Analyses. - Matched funding with government and industry partners for seven Phase 3 technology transition projects.	2.550	-	-
Accomplishments/Planned Programs Subtotals	88.325	113.743	132.336

	FY 2014	FY 2015
Congressional Add: Basic Research Congressional Add ***FY 2015 Plans:*** - Supports increased efforts in basic research that engage a wider set of universities and commercial research communities.	-	5.000
Congressional Adds Subtotals	-	5.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
CYS-01: *CYBER SCIENCES*	-	23.720	58.462	53.774	-	53.774	45.000	47.219	27.000	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 2014	FY 2015	FY 2016
Title: Automated Program Analysis for Cybersecurity (APAC)	23.720	21.318	10.016

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 2014 Accomplishments:
- Improved the effectiveness of prototype tools to enable human analysts charged with curating a DoD app store to keep up with a realistic stream of incoming applications.
- Measured the improvement of analyst productivity and effectiveness through further engagements.
- Used measurements against the program metrics to identify prototype tools that are likely candidates for technology transition.
- Identified transition partners and captured specific user operational needs.

FY 2015 Plans:
- Assess and select prototype tools for experimentation or transition based on their performance on program metrics: probabilities of false alarm, missed detection and human analysis time.
- Conduct further engagements to detect malice hidden in mobile applications, in particular race conditions, complex hidden triggers, and application collusion.
- Measure the improvement of analysts ability to bar malware from DoD app stores using the prototype tools.

FY 2016 Plans:
- Run comparative performance evaluations between program-developed malware detection tools and commercially available tools.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014**	**FY 2015**	**FY 2016**
- Engage in experiments and pilot deployments of prototype tools with transition partners running DoD application stores. - Based on user feedback, make improvements to prototypes to enhance usability in the context of DoD application stores.			
Title: SafeWare ***Description:*** The SafeWare program will develop 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. SafeWare is addressing basic research issues encountered in Safer Warfighter Computing (SAFER) in PE 0602303E, Project IT-03. ***FY 2015 Plans:*** - Formulate 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. - Develop cryptographic code obfuscation methods for which the increase in adversary work factor scales exponentially with respect to a polynomial increase in program runtime overhead. - Assess 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.	-	10.000	13.826
Title: Space/Time Analysis for Cybersecurity (STAC) ***Description:*** The Space/Time Analysis for Cybersecurity (STAC) program will develop 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 flaws in their implementations. Recent news reports have highlighted the first wave of these attacks (CRIME, BREACH, Hash DoS). The	-	12.144	14.573

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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. STAC extends work initiated under the Automated Program Analysis for Cybersecurity (APAC) program to address algorithmic complexity and side channel attacks. ***FY 2015 Plans:*** - Present initial program analysis approaches for identifying vulnerabilities to algorithmic complexity and side channel attacks based on both time and space resource usage. - Develop STAC concept of operations, create example resource usage attack scenarios, and define the rules of engagement for competitive experiments between research and adversarial challenge teams. - Identify 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 capable of reasoning about data and control flow paths in computer programs, identifying inputs adversaries can use to mount algorithmic complexity attacks, and outputs that adversaries can use to mount side channel attacks. - 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.			
Title: Transparent Computing* ***Description:*** *Previously funded in PE 0601101E, Project CCS-02 The Transparent Computing program will develop 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. 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 Plans:*** - Formulate 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.	-	10.000	15.359

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Develop active/continuous testing and adaptive security policy schemes that adjust security posture and usage controls in response to information provided by distributed protection components. - Introduce dynamic behavioral attestation techniques, and propose and analyze scalable algorithms and implementations. ***FY 2016 Plans:*** - Implement adaptive security policy schemes in software prototypes with flexibility and scalability suitable for use on distributed surveillance systems, autonomous systems, and enterprise information systems. - Perform initial assessments of security policy prototypes in simulated laboratory and cloud environments. - Develop and implement behavioral attestation techniques in software prototypes scalable to big data applications. - Develop and implement causal dependency tracking across software/hardware abstraction layers.			
Accomplishments/Planned Programs Subtotals	23.720	53.462	53.774

	FY 2014	FY 2015
Congressional Add: Basic Research Congressional Add ***FY 2015 Plans:*** - Supports increased efforts in basic research that engage a wider set of universities and commercial research communities.	-	5.000
Congressional Adds Subtotals	-	5.000

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

Remarks

D. Acquisition Strategy
N/A

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

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
ES-01: *ELECTRONIC SCIENCES*	-	35.969	37.411	40.401	-	40.401	44.578	36.951	39.796	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 2014	FY 2015	FY 2016
Title: Arrays at Commercial Timescales (ACT) ***Description:*** Phased arrays are critical military subsystems 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 counter adversarial threats under development using commercial-of-the-shelf components that can undergo technology refresh far more frequently. The Arrays at Commercial Timescales (ACT) program will develop adaptive and standardized digital-at-every-element arrays. New advances in digital circuits at every element in an array panel will allow for ubiquitous phased array technology with heretofore unrealized spectral coverage and capabilities. This program will take a fundamental look at the role of digital arrays and how commonality and aggregation can be affected by emerging capabilities. Simultaneously, this effort will focus on the development of arrays which can quickly create different unique RF personalities/capabilities on top of common digital hardware. The project will demonstrate levels of diversity in the use of the electromagnetic spectrum which are severely limited by the current approach of hand-designing the array with heavily specialized RF beamformers that are unique to each system. This program also has related applied research efforts funded under PE 0602716E, Project ELT-01. ***FY 2014 Accomplishments:***	5.442	5.811	5.301

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Initiated development of fundamental design techniques suited to common hardware components for phased array elements that can be seamlessly integrated into a wide range of platforms. - Initiated development of fundamental components and sub-systems enabling common array modules, including active interference mitigation technology, analog processing or beamforming techniques, novel channelization techniques, and filter-less transceiver topologies. -Demonstrated energy efficient bit-stream beamforming with 64% power savings and 68% reduction in chip size. ***FY 2015 Plans:*** - Develop very high speed analog-to-digital (ADC) and digital-to-analog (DAC) converters enabling elemental level digital beamforming of wide bandwidth RF signals, approaching an instantaneous bandwidth of 1GHz. - Develop sample clocking architectures and dithering techniques that enable decorrelation of quantization noise across a phased array antenna. - Develop very high bandwidth switch and switch array technologies that can be toggled from an electrically large standoff distance to enable frequency reconfigurable radiating elements for phased array antennas. - Complete a study with simulation results to showcase performance tradeoffs in the ACT common module as the line of commonality moves closer toward the aperture interface. - Investigate transition paths for fundamental technologies into array systems and common modules under development in the applied research portion of this project. ***FY 2016 Plans:*** - Continue to develop fundamental technologies and techniques for enabling common array modules. - Develop a module that combines N-path filtering and active interference cancellation for testing with commercial off-the-shelf components. - Investigate transition paths for fundamental technologies into array systems and common modules under development in the applied research portion of this project.			
Title: Semiconductor Technology Advanced Research Network (STARNet) ***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 for shared technical hurdles is very attractive.	20.000	20.000	20.000

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**

Research in STARNet is divided into a discovery thrust (ACCEL) and an integration thrust (NEXT) executed by virtual academic centers and focused on combining current or 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.

The STARNet program is unique. It creates a community where industry and government participate as co-sponsors to guide and learn from a large academic research base (including approximately 41 universities, 170 faculty researchers, 605 students, and more than 111 industry associate personnel), with DoD shaping the goals to have direct impact on important long-range DoD needs.

FY 2014 Accomplishments:
- Showed proof-of-concept of novel transistor devices with extremely steep turn-on characteristics, allowing the potential for substantial reductions in operating voltage with correspondingly large reductions in power consumption of military electronics.
- Progressed towards achieving the ultimate scalability of silicon-based computing systems with novel data-centric architectures and innovative parallelism strategies.
- Established a fundamental understanding of multifunctional and spintronics materials, interfaces, architectures and demonstrated primary material synthesis approaches and device concepts towards logic and memory applications.
- Satisfied rapidly increasing DoD need for information processing speed and scalability by designing new strategies using non-deterministic computing paradigms and novel nanodevices to compensate for the increasing unreliability of scaled complementary metal-oxide semiconductor (CMOS) very-large-scale integration (VLSI).
- Established an integrated, networked swarm of pervasive smart sensors and actuators to monitor and control environments such as buildings, cities and ultimately battlefield spaces.
- Demonstrated simulators for accelerator-rich computing architecture, identified the novel communication and storage architecture for power efficient data movement, and explored robust and secure computation architecture.
- Monitored and assessed progress towards technical goals proposed by Centers, including reductions of 100 times in the power consumption of devices, 100 - 10,000 times lower energy consumption in logic switches, 10 - 100 times higher computational energy efficiency, scalability of technologies to sub-10 nanometer dimensions, development of novel computing architectures, and highly energy-efficient information processing systems inspired in the nervous system.

FY 2015 Plans:
- Investigate the feasibility of advanced two-dimensional semiconductor materials for extremely low power devices and develop the nanofabrication methods as well as establish the theory, modeling and simulation tools.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Research fundamental limitations of scaling multifunctional and spintronics materials and examine device characteristics as well as demonstrate the advanced devices. - Develop the scalable silicon-based computing system architecture by exploring the benefits of heterogeneously integrating emerging nano-technologies into silicon-based designs. - Develop 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-CMOS and CMOS fabrics, and accelerate the deployment of beyond-CMOS and CMOS nanoscale fabrics via nanofunctions and nanoprimitives. - Develop 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:*** - Design VLSI and analog circuits based on novel steep-turn-on transistor devices for applications such as lower power imagers, pattern recognition, and scavenging self-powered electronics with extremely low energy-delay product. - Develop multifunctional and spintronics devices and fabrication techniques to enable logic and memory circuits with increased complexity. - Develop the scalability of silicon-based computing system concepts into the 2020-2030 timeframe to meet the performance, power and cost demands for DoD applications. - Discover, develop, and demonstrate bio- and neuro-inspired information processing architectures that approach the efficiency of brain computation, while aligning well with emerging beyond-CMOS nanoscale fabrics. - Demonstrate sensor swarm applications for Defense requirements such as warfighter situational awareness and assess system characteristics and potential advantages.			
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 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	-	3.100	6.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 Plans:*** - Optimize wavelength dispersion and low-threshold operation of microresonator based combs. - Explore materials and novel devices for efficient on-chip second harmonic generation. ***FY 2016 Plans:*** - Demonstrate low-threshold octave-spanning microresonator 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.			
Title: Next Generation Atomic Clock (NGAC) ***Description:*** 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 wide availability of atomic-quality timing in portable battery-powered applications. The Next-Generation Atomic Clock (NGAC) program will develop a next-generation chip-scale 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. The NGAC program will develop a Chip-Scale Atomic Clock achieving temperature coefficient of frequency of <10^-15/degrees Celsius and frequency drift < 10^-12/month. This will enable precise timing on low-CSWaP platforms with extended mission duration. In order to achieve these performance metrics, novel approaches to atomic confinement and interrogation will be	-	-	4.600

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
explored and new enabling components will be developed. Applied research for this program is funded within PE 0602716E, Project ELT-01. ***FY 2016 Plans:*** - Develop low-CSWaP application-specific laser devices, optical modulators, shutters, and isolators. - Demonstrate integration of application-specific optical components into robust photonic integrated circuits. - Develop techniques for alkali metal vapor pressure control over the full DoD temperature range. - Develop low-CSWaP ultra-high vacuum technology operating without perturbative magnetic fields. - Demonstrate clock operation with integrated enabling component devices.			
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 (SOA) 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 or ultimately by the battery self-discharge. This program will investigate emerging materials and devices and quantify their impact on system performance. 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 2016 Plans:*** - Develop fundamental materials, devices, and techniques for low energy collection, processing and detection of sensor and communications signals. - Investigate transition paths for fundamental technologies into radio frequency communications and physical sensor systems under development in the applied research portion of this project.	-	-	1.500
Title: Electronic Globalization ***Description:*** Approximately 66% of all installed semiconductor wafer capacity is in Asia. This creates a significant risk as off-shore manufacturing of microelectronic components could introduce various vulnerabilities to DoD systems that utilize these	-	-	3.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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, theft of U.S. intellectual property, and non-authorized use of these electronic components in adversary defense systems. The Electronic Globalization program will examine various approaches for trusting circuits in an untrusted environment. It will develop the abilities to design circuits with functionality that is benign in an untrusted environment. Basic Research activity will focus on the characterization of materials and structures which enable the trust of circuitry. This trust will be provided by the ability to create back end of line processing, or other similar mechanisms, to complete or personalize a circuit after it has been through the majority of the traditional supply chain. Applied research for the program is budgeted in PE 0602303E, Project IT-02. ***FY 2016 Plans:*** - Define the value proposition offered by the proposed material, identifying a specific Concepts of Operations (CONOPS). - First pass intrinsic physics-level modeling and simulation of structures and materials. - Design of proof-of-concept test sites. - Fabricate test coupons and characterization of new morphological materials and structures. - Characterization of experimental hardware.			
Title: Microscale Plasma Devices (MPD) ***Description:*** The goal of the Microscale Plasma Devices (MPD) program is to design, develop, and characterize MPD technologies, circuits, and substrates. The MPD program will focus 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 will be 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. It is envisaged that both two- and multi-terminal devices consisting of various architectures will be developed and optimized under the scope of this program. MPDs will be 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 is focused on fundamental MPD research and will advance scientific knowledge based on the study of several key MPD design parameters. These parameters include ultra-high pressure and high carrier density regimes. MPD will focus on expanding the design space for plasma devices enabling revolutionary advances in micro-plasma device performance. It is expected that MPD will develop 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.	5.000	2.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 2014 Accomplishments:*** - Completed optimized microcavity designs achieving parameters and uniformity necessary for < 100 picosecond device switching speeds needed for robust survivability in high power electromagnetic fields. - Finalized studies of plasma in extreme environments (radiation and temperature) to demonstrate robust electronics capable of surviving in harsh environments orders of magnitude longer than current state of art silicon Complementary Metal-Oxide Semiconductor (CMOS). - Determined feasibility of controlling infrared and light via manipulation, absorption and switching utilizing microscale plasmas. - Completed device modeling based on characterization of fabricated microscale plasma devices and provided results to circuit and microsystem integrators for use in DoD system designs. - Continued studies of 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. ***FY 2015 Plans:*** - Complete investigations examining scaling properties for plasma devices in terms of size, density, robustness and switching speed. - Finalize 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. - Complete the optimization of devices that perform from RF through light frequencies. - Transition 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.			
Title: Micro-coolers for Focal Plane Arrays (MC-FPA) ***Description:*** The Micro-coolers for Focal Plane Arrays (MC-FPA) program will develop 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 will exploit 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 complementary metal-oxide semiconductor (CMOS) electronics will be used to demonstrate an integrated cold head and	1.500	1.500	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
compressor, all in a semiconductor chip. This program has related applied research efforts funded under PE 0602716E, Project ELT-01. ***FY 2014 Accomplishments:*** - Designed the cold stage with significantly reduced processing steps (from 20 down to 13) and optimized the design of the J-T valve for 100 mW cooling. - Completed the mask layout for the compressors (5.5 mm X 5.5 mm) and individual inlet and outlet valves. - Finalized the selection of all the parts for the year-1 single-stage micro-cryogenic cooler demonstration. - Completed the cold stage fabrication and 50% for the compressor. - Designed a novel coupling approach between the cold stage and the compressor using a Polydimethylsiloxane (PDMS) coupler. - Developed a model for a two-phase heat transfer and fluid flow in the cold stage. - Demonstrated atomic layer deposition (ALD)-based, nano-scaled compression chamber. - Designed a chip-scale, J-T cold-head for a 640 x 480 extended shortwave infrared (e-SWIR, 1-2.4 micrometer cutoff) FPA with 4-6 micrometer unit cell size. - Developed all the critical technologies for the demonstration of a single-stage micro-cooler with an integrated piezoelectric compressor and cold-head with following metric: 30mm x 20mm x 10mm; 50 g. - Developed an alternative system configuration requiring a pressure ratio of 2:1 instead of 4:1. ***FY 2015 Plans:*** - Demonstrate a single-stage micro-cooler with an integrated piezoelectric compressor and cold-head with the following metric: 30 mm x 20 mm x 10 mm; 50 g. - Finalize design and demonstrate a three stage J-T micro-cooler operating down to 195 K. - Finalize design of a five-stage J-T micro-cooler operating down to 150 K with 350 mW heat lift. - Improve the reconfigurable fluid interconnect developed above and apply such a scheme to improve the fabrication yield of the wafer-scale integrated micro-cryogenic cooler. - Integrate the MEMS compressors and the cold stages into a five-stage wafer-scale integrated micro-cryogenic cooler for the final demonstration. - Demonstrate J-T micro-cooler operating down to 150 K with 350 mW heat lift.			
Title: Diverse & Accessible Heterogeneous Integration (DAHI) ***Description:*** Prior DARPA efforts have demonstrated the ability to monolithically integrate a limited set of different semiconductor types to achieve near-ideal "mix-and-match" capability for DoD circuit designers. Specifically, one such program was the Compound Semiconductor Materials On Silicon (COSMOS) program, in which transistors of Indium Phosphide (InP) could 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	4.027	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Integration (DAHI) program took this capability to the next level, ultimately offering the seamless co-integration of a variety of semiconductor devices (for example, Gallium Nitride, Indium Phosphide, Gallium Arsenide, Antimonide-Based Compound Semiconductors), micro-electromechanical (MEMS) sensors and actuators, photonic devices (e.g., lasers, photo-detectors) and thermal management structures. This capability revolutionized our ability to build true "systems on a chip" (SoCs) and allowed dramatic size, weight and volume reductions for a wide array of system applications. The Basic Research part of this program focused on the development of new hetero-integration processes and capabilities that were demonstrated in application-specific circuits and transferred into the manufacturing flow. This program has applied research efforts funded in PE 0602716E, Project ELT-01, and advanced technology development efforts funded in PE 0603739E, Project MT-15. ***FY 2014 Accomplishments:*** - Developed new CMOS-compatible processes to achieve heterogeneous integration with diverse types of compound semiconductor transistors, MEMS, and non-silicon photonic devices. - Fabricated and tested heterogeneously integrated ultra-low-noise laser sources and on-chip laser radar systems. - Developed noise measurement methodology with sensitivity beyond state-of-the-art in order to test the advanced lasers and optoelectronic signal sources being developed within DAHI.			
Accomplishments/Planned Programs Subtotals	35.969	32.411	40.401

	FY 2014	FY 2015
Congressional Add: Basic Research Congressional Add ***FY 2015 Plans:*** - Supports increased efforts in basic research that engage a wider set of universities and commercial research communities.	-	5.000
Congressional Adds Subtotals	-	5.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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

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

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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
MS-01: *MATERIALS SCIENCES*	-	93.010	73.077	70.368	-	70.368	69.966	72.233	73.780	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 2014	FY 2015	FY 2016
Title: Nanoscale/Bio-inspired and MetaMaterials	16.205	15.500	19.750

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 optical based metamaterial imaging systems capable of detecting objects in cluttered environments and around or through structural obscurants.

FY 2014 Accomplishments:
- Designed materials with decoupled property combinations (e.g., strength/density, stiffness/thermal expansion) using architecture-to-property trade space capability.
- Demonstrated fabrication methods amenable to scaling and that permit architectural control capable of maintaining decoupled properties.
- Demonstrated targeted enhancement to material properties (e.g., tailored coefficient of thermal expansion (CTE)/energy dissipation and load bearing stiffness).
- Established manufacturability and amenability to scale up and provided fabrication and characterization data package.
- Initiated development of synthetic methods for preparing large sequence controlled polymer libraries.

FY 2015 Plans:
- Develop a method for screening non-natural polymer libraries for designed properties such as binding to target molecules.
- Develop a method for sequencing non-natural polymers at low concentrations.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Explore and develop modeling tools for the physics of scattering in metamaterials and the application of using ultra-short laser pulses to see and detect objects through various obscurants. ***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 generate catalysts. - Investigate engineered optical metamaterials for manipulating optical fields in spatial, spectral and temporal domains to enable a single optical device to simultaneously perform multiple functions in different domains. - Investigate linear refraction metamaterials for minimizing optical aberrations and improving performance of imaging and non-imaging optics over wide angles of light incidence, while minimizing optics size and weight.			
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, advanced armor, ultra-precision air and water purification systems, and advanced armor protection. ***FY 2014 Accomplishments:*** - Validated computational tools against known high-pressure materials and developed multistep pathways to selected extended solids. - Applied synthesis techniques to, and initiated synthesis of, intermediates projected to lead to selected extended solids. - Initiated development of methods to stabilize extended solids at ambient temperatures and pressures. ***FY 2015 Plans:*** - Continue synthesis of suites of intermediates to lead to selected extended solids. - Characterize the physical, structural, and chemical properties of intermediates synthesized.	6.500	13.300	19.503

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Further the development of methods to stabilize extended solids at ambient temperatures and pressures. - Based on computational analysis and experimental results, initiate design retrosynthetic pathways that are synthetically achievable for multistep reaction schemes to fabricate extended solids at reduced pressures. - Identify novel approaches for enabling 3 dimensional (3D) assemblies of nanoscale material constructs into micron-scale structures while preserving desirable nanoscale material properties. - Select candidate nanoscale material systems with superior material properties that are amenable to 3D assembly processes. - Identify promising "pick and place" technologies for assembling 3D micron-scale constructs into cm-scale structures. ***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. - Demonstrate methods to synthesize bulk cubic boron nitride at reduced pressure with purities of >50%. - 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. - Demonstrate the ability to assemble micron-scale, 3D, multiple material structures from nanoscale material constructs while preserving desirable nanoscale material properties. - Demonstrate pick and place assembly of cm-scale materials from micron-scale constructs while preserving desirable nanoscale material properties.			
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, and table-top sources of coherent X-rays, isolated attosecond pulses, and intense neutron sources for medical and non-medical applications. 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	17.889	19.400	22.100

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
entirely new fields in simultaneous remote sensing, identification, and quantification of multiple trace materials in spectrally cluttered backgrounds. ***FY 2014 Accomplishments:*** - Demonstrated quantum mechanically secure communications at a secure key information rate greater than 50 Mb/s and 5 bits per received photon. - Demonstrated a 30 gigahertz (GHz) oscillator using optical frequency division with a micro-frequency comb. - Demonstrated continuous wave operation of a monolithic solid-state laser with milliwatt average output power for integration into a rack mountable ultra-low noise microwave source. - Fabricated silicon nitride microresonators and bulk electro-optically generated frequency comb sources with multiple comb lines for pulse shaping applications including RF photonic filtering. - Designed pump and seed lasers for optical parametric chirped pulse amplification for improved X-ray generation efficiency in the water window spectral region. - Demonstrated pump lasers with pulse energies of 2 joules at 800 nanometers and 1 millijoule at 1.8 micron wavelengths for efficient extreme ultraviolet and soft X-ray attosecond pulse generation. ***FY 2015 Plans:*** - Demonstrate 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. - Demonstrate on-chip frequency comb and pulse shaping components utilizing indium phosphide based photonic integrated circuit technology and evaluate with bulk scale reference combs. - Demonstrate high flux soft X-ray production in the biologically critical water window spectral region and use this source for preliminary X-ray imaging demonstrations on the nanometer scale in the water window. - Demonstrate high efficiency-per-shot laser driven neutron production and construct increased repetition rate sample target inserter and laser amplifiers to improve overall neutron flux for radiography applications. - Demonstrate and control 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. - Develop and control micro-resonator based frequency comb sources in the visible and mid-infrared spectral region. - Demonstrate 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. - Demonstrate a remotely operating quartz microwave oscillator slaved via optical frequency comb based free-space (wireless) time and frequency transfer.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Demonstrate femtosecond time-resolved imaging at the nanometer scale with soft X-rays generated via high harmonic generation (tabletop scale X-ray source). - Finalize laser design and optimize neutron generation source for laser-driven neutron generation. - Demonstrate stability and characterization capabilities of EUV/Soft X-ray attosecond end-station by measuring and characterizing isolated attosecond (10^-18 seconds) pulses. - Demonstrate proof-of-concept for micro-resonator based comb sources in the ultraviolet spectral region. - Demonstrate proof-of-concept for micro-resonator based comb sources in the far-infrared and THz spectral regions. - Demonstrate massively parallel spectroscopy for the detection of multiple trace species using micro-resonator based optical frequency combs in multiple spectral regions in a lab setting.			
Title: Enabling Quantum Technologies ***Description:*** This thrust emphasizes 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 will also exploit 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 will examine other novel classes of materials and phenomena such as plasmons or Bose-Einstein Condensates (BEC) that have the potential to provide novel capabilities in the quantum regime, such as GPS-independent navigation via atom interferometry and communications, and ultrafast laser technologies. ***FY 2014 Accomplishments:*** - Demonstrated a single diamond nitrogen vacancy magnetometer with < 10 nm resolution that is compatible with imaging biological systems. - Validated the performance of a compact (< 10 liters) portable optical clock with a timing accuracy 10 times better than satellite GPS clocks. - Demonstrated prototypes for macroscopic quantum communications systems at secure long haul communications distances. - Derived optimal decoupling between secure bit rate and loss in long-haul quantum communications. - Implemented macroscopic quantum communications testbed capable of simulating realistic conditions (loss, noise, and decoherence) through the modern fiber-optic telecommunications grid. ***FY 2015 Plans:*** - Develop compact optomechanical gyroscopes. - Demonstrate 50 nm resolution for magnetic imaging of living cells. - Sense functional changes of electronic spin labels in biomolecules (e.g., proteins, lipids) with high spatial and temporal resolution. - Validate optimized performance of slow-beam-optical-clock.	30.543	19.877	9.015

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Integrate prototype macroscopic quantum communications system into quantum communications testbed. - Quantify performance of prototype macroscopic quantum communications system under realistic conditions (loss, noise, decoherence) and over secure long haul communications distances. - Develop an initial mathematical modeling framework for predicting the emergence of quantum behavior in complex systems. ***FY 2016 Plans:*** - Explore analytical techniques for characterizing the emergence of quantum effects in complex systems across scales of time and space. - Design an open source, agent based hardware/software platform for evaluating algorithms for modeling quantum effects in complex systems across multiple scales.			
Title: Fundamentals of Physical Phenomena ***Description:*** The thrust obtained insights into physical aspects of natural phenomena such as magnetospheric sub-storms, fire, lightning, and geo-physical phenomena. New fundamental understandings of these phenomena have enabled the ability to predict and exploit these physical processes. A major emphasis of this thrust was to provide predictive models for the interactions between plasmas and electromagnetic waves across a range of energy and length scales, and into new regimes. Specific efforts that fell under this heading were foundational studies on the initiation, propagation, and attachment of lightning, and their associated emissions; the critical factors affecting magnetospheric sub-storms; and understanding and quantifying the interaction of electromagnetic and acoustic waves with the plasma in flames. ***FY 2014 Accomplishments:*** - Gathered in-situ measurements of oceanic lightning e-fields, current and X-rays using synchronized unmanned air vehicle (UAV), balloon, buoy and lighting mapping array. - Measured electron density within the D region of the ionosphere by measuring the aperiodic irregularities (API) structures formed by high frequency (HF) standing waves from the upward and downward propagating heater beam. - Experimentally measured plasma outflow by HF heating, lower hybrid and Whistler waves generation, very low frequency (VLF) waves generation and propagation into space.	8.873	-	-
Title: MesoDynamical Architectures (Meso) ***Description:*** The Meso program exploited recently discovered physics at small scales to demonstrate transformative communication, sensing, and computing technologies for the DoD. The length scale targeted was between the nanoscale and macroscale, known as mesoscale, and is an important intersection between classical and quantum mechanical effects where new combined phenomenon has emerged. The program was divided into four thrusts: nonlinearity and noise, coherent collective dynamics, information transduction, and coherent feedback control. In each of these thrusts, performers focused on demonstrating specific technologies that have significant impact on DoD capabilities. Technologies included high-performance	13.000	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
frequency sources, transistors operating at 100 times lower power than current state-of-the-art, a hand-held biotoxin detector, and attojoule optical switches. ***FY 2014 Accomplishments:*** - Produced the only topological insulator thin (less than 100 nm) materials in the world with topological surface state dominated conduction up to room temperature. This had previously been observed only at cryogenic temperatures, paving the way for fabrication of practical devices to advance DoD's mission. - Discovered spin torque in topological insulator materials over 10 times larger in magnitude than state-of-art at room temperature, highly promising for advanced memory devices with over 10 times lower power required for switching at the same speed of state-of-art, or switching 10 times faster than state-of-art at the same power. - Demonstrated chip-scale, wavelength insensitive second order Silicon Radio Frequency (RF) photonic filters with ~3 GHz pass-band center frequency, >70 dB of rejection over 66% of the center frequency of operation, and undistorted filter response over high optical powers exceeding 100 mW. This eliminates fabrication, design and stabilization constraints of state-of-art RF filtering schemes and dramatically reduces size, weight, power and cost to enable dense integration of RF/Microwave and complementary metal-oxide semiconductor (CMOS) on-chip for nano-Unmanned Aerial Vehicle. - Integrated microfluidic platform and CMOS electronics into the bio-molecular sensor interface by a heterogeneous integration process with demonstrated capability of detecting 1 pM concentration of a toxin in 100 mM background liquid substance without probes or labels. Detected single mass isotope substitutions in amino acids, and sub-10 pM concentration of a neurotoxin in 500nl of blood serum. Extended the scientific knowledge developed in the project to quantum-tunneling-based platforms capable of enabling multi-functional memory devices and on-chip clocks. - Fabricated the first piezoelectronic transistor with a promising path toward achieving >10,000 ON/OFF ratio at 0.1 volts and better processing efficiency than conventional CMOS. Scaled piezoelectric films with full functionality to 300 nm thickness. Invented a new micrometer-scale Radio Frequency switch application of the piezoelectronic transistor with the promise of superior performance than alternate hardware implementations. - Demonstrated planar, chip-scale single-photon conversion between near-visible and telecommunication optical bands with high efficiency for microWatts drive power levels. - Designed new coherent nano-photonic circuit architectures capable of tolerating large error rates per individual components, using substantial coherent feedback to prevent quantum fluctuation noise buildup through multiple logic stages. - Fabricated robust nano-photonic circuits with multiple components switching at 100s of picoseconds and femto-Joule energy (or about 100 photons).			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Reduced the phase noise of truly Micro Electro-Mechanical Systems (MEMS)/Nano Electro-Mechanical Systems (NEMS) frequency sources to produce the next generation (Phase 3) of devices with better temperature and acceleration stability in a compact package.			
Accomplishments/Planned Programs Subtotals	93.010	68.077	70.368

	FY 2014	FY 2015
Congressional Add: Basic Research Congressional Add ***FY 2015 Plans:*** - Supports increased efforts in basic research that engage a wider set of universities and commercial research communities.	-	5.000
Congressional Adds Subtotals	-	5.000

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

Remarks

D. Acquisition Strategy
N/A

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

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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
TRS-01: *TRANSFORMATIVE SCIENCES*	-	31.905	29.417	30.113	-	30.113	28.535	30.831	40.377	42.377	-	-

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 2014	FY 2015	FY 2016
Title: Living Foundries	10.973	9.644	7.750

Description: The goal of the Living Foundries program is to create a revolutionary, biologically-based manufacturing platform to provide new materials, capabilities, and manufacturing paradigms 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. However, the DoD's ability to harness this platform is rudimentary. 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. The program will enable the rapid and scalable development of previously unattainable technologies and products (i.e., those that cannot be accessed using known, synthetic mechanisms) leveraging biology to solve challenges associated with production of new materials (e.g., fluoropolymers, enzymes, lubricants, coatings and materials for harsh environments), novel functions (e.g., self-repairing and self-regenerating systems), biological reporting systems, and therapeutics to facilitate new solutions and enhancements to military needs and capabilities. Ultimately, Living Foundries aims to provide game-changing manufacturing paradigms for the DoD, enabling distributed, adaptable, on-demand production of critical and high-value materials, devices and capabilities in the field or on base. Such a capability will decrease the DoD's dependence on tenuous material supply chains that are vulnerable to political change, targeted attack, or environmental accident.

If successful, Living Foundries will do for biology what very-large-scale integration (VLSI) did for the semiconductor device industry: enable the design and engineering of increasingly complex systems to address and enhance military needs and capabilities. Living Foundries will develop and apply an engineering framework to biology that decouples biological design from fabrication, develops and yields design rules and tools, and manages biological complexity through simplification, abstraction, and standardization of both processes and components. The result will be rapid design, construction, implementation and testing of complex, higher-order genetic networks with programmable functionality and DoD applicability. Research thrusts include developing the fundamental tools, capabilities and methodologies to accelerate the biological design-build-test cycle,

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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 2014	FY 2015	FY 2016
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. Specific tools and capabilities include: interoperable tools for design and modeling; automated, modular and standardized fabrication and genome-scale engineering processes; modular regulatory elements, devices and circuits for hierarchical and scalable engineering; standardized test platforms and chassis; and novel approaches to process measurement, validation, and debugging. Applied research for this program is budgeted in PE 0602715E, Project MBT-02. ***FY 2014 Accomplishments:*** - Began research and development on incorporation of new, non-natural components into bio-manufactured materials (including non-natural amino acids and an expanded set of atomic elements) to broaden the set of new materials and functions. - Began initial demonstration of automated, genome-scale cellular engineering process platforms that simultaneously increase the scale and complexity of experimentation and decrease the cost and time to engineer a new production system. - Continued research and development of tools and methodologies to program, reprogram, and enable spatio-temporal control and feedback for engineered systems. - Continued to design and assess production pathways for novel materials. - Developed novel algorithms and software that link the design of genetic systems to their assembly and characterization data to begin integrating the design of systems with their construction and ultimate testing/debugging. - Began development and demonstration of tools to enable engineering of currently intractable chassis for novel and enhanced functionalities and materials production. ***FY 2015 Plans:*** - Examine design tool innovations to enable forward engineering of novel genetic systems. - Investigate design evaluation tools to enable massively parallel testing, validation, and verification of engineered systems. - Continue development of automated and scalable, large-scale DNA assembly and editing tools and processes. - Research 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 design 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.			
Title: Open Manufacturing	3.200	3.197	1.538

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
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 2014 Accomplishments:*** - Developed a fundamental understanding of the impact on quality features and parameters to establish process windows for new rapid process technologies. - Developed metrology methods to support probabilistic process modeling in metals additive manufacturing and bonded composite processing. - Developed a fundamental understanding of the interaction between electromagnetic fields and refractory metals and metal matrix composites based on particle size and material. ***FY 2015 Plans:*** - Develop 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. - Demonstrate Micro-Induction Sintering (MIS) method for additive manufacture of metal and/or ceramic materials in complex geometries. - Demonstrate approach to verifying, validating, and quantifying uncertainty in the developed rapid qualification frameworks. ***FY 2016 Plans:*** - Characterize material properties of refractory and metal matrix composites 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.			
Title: Biological Robustness in Complex Settings (BRICS)* ***Description:*** *Formerly ACE (Advanced Capabilities in Engineering Biology) The Biological Robustness in Complex Settings (BRICS) program will leverage newly developed technologies for engineering biology towards enabling radical new approaches to solving National Security challenges. Engineering biology is emerging as a new field 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	-	8.000	10.825

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
other applications. This rapidly developing technological capability opens the door to new national security applications that have heretofore 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 of 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 Plans:*** - Investigate methods to engineer microorganisms that are stable over long time periods under complex growth conditions. - Investigate methods to engineer communities of microorganisms with reliably controlled population dynamics. - 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. - Demonstrate methods to rationally engineer functional microbial communities of increasing complexity.			
Title: Applying Biological Complexity at Scale ***Description:*** Applying Biological Complexity at Scale will pursue new insights derived from biological complexity and living-system dynamics to develop applications to enhance global-scale stability, transform hostile environments, and ensure human well-being. Biological systems operate over an enormous range of spatial, physical, and temporal scales and span individual cells to multi-organism systems. Enhanced understanding of the basic processes associated with biological network interactions and communication will enable novel approaches and technology development to enhance national security, ranging from infectious disease mitigation or prevention, to predicting and leveraging behavior of microbial populations or even distributed human networks. Key advances expected from this research will include the identification of stable, scalable features and mechanisms of biological networks. Such information will allow the determination of a bio-system's state and enable the prediction of state, as well as where there are inflection points that can either be exploited, or that must be preserved in order to maintain equilibrium (e.g., microbial community dynamics and their applications). ***FY 2016 Plans:*** - Investigate dynamics and thresholds for transgene stability/instability in systems of infectious disease vectors. - Study methods for achieving transient phenotypes in infectious disease vectors. - Investigate predictive design rules and engineering approaches for integrated biosystems. - Investigate microbial community evolution and communication as it applies to their application (e.g., microbiome impacts on health or catabolism).	-	-	10.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Research large-scale biological system responses to threats and understand defining characteristics of varying ecological states.			
Title: Social Media in Strategic Communication (SMISC) ***Description:*** The Social Media in Strategic Communication (SMISC) program is developing 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 will develop technology and a new supporting foundational science of social networks that will enable warfighters to defend against malevolent use of social media and to counter extremist influence operations. ***FY 2014 Accomplishments:*** - Refined algorithms for real-time detection and tracking of memes at scale. - Improved specialized algorithms to recognize purposeful or deceptive messaging and misinformation, persuasion campaigns, and influence operations across social media. - Designed algorithms to identify the minimum set of sensors for a given social system based on models used to predict the social dynamics stability distribution and impact on link characteristics. - Designed scalable, efficient, and accurate social malware detection algorithms. - Extended algorithms developed for text-centric social media and micro-blogging to new social multi-media platforms. ***FY 2015 Plans:*** - Integrate algorithms for meme detection and tracking with algorithms for detecting deception, persuasion, and influence operations. - Develop high fidelity diffusion models for messages, narratives, and information across social media. - Combine integrated algorithms with diffusion models to create predictive simulations for the spread of given messages, narratives, and information. - Refine algorithms for sentiment analysis of content on developing social multi-media platforms.	14.620	6.076	-
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	3.112	2.500	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
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. ***FY 2014 Accomplishments:*** - Characterized transience of alternative semiconductors and other electronic materials for device components. - Began developing multiple transience mechanisms, including demonstrating mechanically, electrically, and optically triggered transience. - Began developing electronic materials that exhibit a useful combination of transience and the necessary physical characteristics required for sufficient electronic performance. - Developed polycarbonate-based materials, stress-engineered substrates, hydrogels, and Complementary-Metal-Oxide-Semiconductor (CMOS) process-comparable thin films to allow fast etching, dissolution, sublimation, and fragmentation mechanisms for control of transience effects. - Developed mechanical, stress, corrosion rate modeling tools to predict transience effects. - Initiated the systematic study of novel transient packaging materials. ***FY 2015 Plans:*** - Establish electronic materials that exhibit a useful combination of transience and the necessary physical characteristics required for sufficient electronic performance. - Enhance device modeling tools that incorporate transience effects.			
Accomplishments/Planned Programs Subtotals	31.905	29.417	30.113

C. Other Program Funding Summary ($ in Millions)

N/A

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

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Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	48.066	60.757	56.544	-	56.544	62.807	65.685	67.882	66.456	-	-
MED-01: *BASIC OPERATIONAL MEDICAL SCIENCE*	-	48.066	60.757	56.544	-	56.544	62.807	65.685	67.882	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 blast-induced traumatic brain injury as well as health monitoring and the prevention of 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. For traumatic brain injury, this project will establish a fundamental understanding of brain function, short-term memory and the mechanism(s) of injury induced by exposure to blast. To enable in-theater, continuous analysis and treatment of warfighters, this project will also explore diagnostic and therapeutic approaches, such as the use of bacterial predators as therapeutics against infections caused by antibiotic-resistant pathogens. Advances in this area may be used as a preventative measure to mitigate widespread disease.

B. Program Change Summary ($ in Millions)	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	49.500	49.848	44.700	-	44.700
Current President's Budget	48.066	60.757	56.544	-	56.544
Total Adjustments	-1.434	10.909	11.844	-	11.844
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	10.909			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-1.434	-			
• TotalOtherAdjustments	-	-	11.844	-	11.844

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

	FY 2014	FY 2015
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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014**	**FY 2015**
Congressional Add Totals for all Projects	-	10.909

Change Summary Explanation

FY 2014: Decrease reflects the SBIR/STTR transfer.
FY 2015: Increase reflects congressional add.
FY 2016: Increase reflects exploration of new methods to maintain and optimize warfighter health, and harness biological technologies and systems.

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
Title: Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT)	40.500	49.848	33.400
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 synthetic biology 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 2014 Accomplishments:*** - Demonstrated in mammalian cells the function of a synthetic circuit that can integrate multiple signals associated with health status and respond with a targeted change in cell function. - Demonstrated the ability to generate synthetic nucleic acid and protein circuit components that respond to an exogenously supplied small molecule drug trigger. - Demonstrated biostabilization reagents/materials with biospecimen types and physical formats appropriate for integration into devices for collection and transport of patient samples for diagnostic analysis, and integration into on-person diagnostic devices. - Demonstrated signal amplification methods in conjunction with processing/assay methods.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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 2014	FY 2015	FY 2016
- Optimized sample preparation methods and tested efficacy using biospecimens representative of those either self-collected under low-resource settings or collected by trained professionals at the physician-office settings to assist the diagnosis of an individual. - Developed advanced materials for incorporation in disposable diagnostic devices. - Optimized advanced microfluidic methods for no/low power flow control. - Demonstrated delivery of synthetic oligonucleotide constructs to cells appropriate to produce an antibody response. - Demonstrated antibody and immunoadhesin production targeted to specific disease classes. - Optimized antibody sequence for maximal therapeutic strength of immune response in vivo. ***FY 2015 Plans:*** - Collect serum from ill, convalescent, or immunized humans and identify two or more antibodies that in combination provide disease-specific protection. - Demonstrate ability to administer nucleic acid encoding multiple antibodies to protect against existing, unmet, clinical targets; emerging global infectious diseases; and known, engineered biothreats. - Demonstrate onset of protection within hours after delivery and duration of therapeutic response greater than IV administered antibodies. - Demonstrate protective response and duration of antibody-encoding nucleic acid constructs greater than that conferred by administration of preformed antibodies against infectious disease in a large animal model. - Demonstrate optimized, high sensitivity assay methods for protein and nucleic acid biomarkers, suitable for incorporation in deployable devices. - Demonstrate advanced materials properties and incorporation of developed materials into disposable assay formats. - Demonstrate advanced methods for reagent stabilization and delivery for assays developed for deployable devices. - Demonstrate sample preparation methods in conjunction with developed assays and quantify performance metrics. - Demonstrate performance of developed assays using advance no/low power microfluidic methods. - Measure performance of developed diagnostic methods and demonstrate capability to measure clinically relevant analyte levels in appropriate biospecimen matrices. - Demonstrate 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. - Demonstrate 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. - Demonstrate the ability to generate a synthetic antibody via continuous evolution that can specifically bind to a defined target in mammalian cells.			

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Investigate 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. - 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.			
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 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. This thrust will also investigate the adaptability of microorganisms as well as the process for microbial community evolution. Advances in these areas may be applied in a range of biological technologies including the development of novel therapeutics and biocentric sensors. ***FY 2016 Plans:*** - Investigate predator effectiveness against pathogens of interest. - Initiate basic science studies of the relevant underlying mechanisms of predation. - Begin basic science studies to enhance understanding of biological adaptability in response to external pressures. - Identify and understand fundamental mechanisms that control the transition between unicellular and multicellular function. - Examine biological basis for naturally occurring evolutionary advances. - Investigate novel methods to integrate evolved biological traits. - Research basic science processes by which bacteria grow and spread throughout a community.	-	-	10.103
Title: Analytics and Adaptation of Human Resilience	-	-	13.041

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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 2014	FY 2015	FY 2016
Description: The Analytics 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 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 disease such as multi-drug resistant pathogens. ***FY 2016 Plans:*** - Develop human-relevant animal models of infection across multiple resilient species. - Apply diagnostic technologies that can rapidly detect pathogen load and characterize the different stages of infection in multiple animal species. - Correlate experimental results with bioinformatics datasets to discover key markers of tolerance. - Develop a bioinformatics database to house acquired clinical retrospective data.			
Title: Human Assisted Neural Devices ***Description:*** The Human Assisted Neural Devices program developed the scientific foundation for understanding the language of the brain for application to a variety of emerging DoD challenges, including improving performance on the battlefield and returning active duty military to their units after injury. This required an understanding of neuroscience, significant computational efforts, and new material design and implementation. Key advances from this research include determining the nature and means through which the brain utilizes sensory inputs to plan and execute behavioral outputs, and discovering the mechanisms and dynamics underlying neural computation and reorganization. These advances enabled restoration of sensorimotor function through the use of devices programmed to bridge gaps in the injured brain. Further, modeling of the brain progressed to an unprecedented level with this novel approach. A key aspect of this effort was to develop non-destructive neuronal imaging and control techniques that are capable of rapid analysis and interpretation of brain tissue alterations at the cellular scale. Additional research under this effort generated new methodologies to understand the structural and functional relationships between individual neurons through direct, high-resolution, optical imaging of neuron populations of interest as well as the entire brain. ***FY 2014 Accomplishments:*** - Demonstrated the ability of non-human primates to perform a dexterous sensorimotor task through the use of a neural interface, without the use of neural spike recordings.	7.566	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014**	**FY 2015**	**FY 2016**
- Explored initial models of the brain driven by understanding of the physical connections between individual neurons of highly trained animals conducting a specific task. - Generated initial, high-resolution, optical connectivity activity data and corresponding very-large neural data sets.			
Accomplishments/Planned Programs Subtotals	48.066	49.848	56.544

	FY 2014	**FY 2015**
Congressional Add: Basic Research Congressional Add ***FY 2015 Plans:*** 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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	121.152	159.790	114.262	-	114.262	109.069	109.817	120.852	116.651	-	-
BT-01: *BIOMEDICAL TECHNOLOGY*	-	121.152	159.790	114.262	-	114.262	109.069	109.817	120.852	116.651	-	-

A. Mission Description and Budget Item Justification

This Program Element is budgeted in the applied research budget activity because it focuses on medical related technology, information, processes, materials, systems, and devices encompassing a broad spectrum of DoD challenges. Bio-warfare defense includes the capability to predict and deflect evolution of natural and engineered emerging pathogen threats, and therapeutics that increase survivability within days of receipt of an unknown pathogen. Continued understanding of infection biomarkers will lead to development of detection devices that can be self-administered and provide a faster ability to diagnose and prevent widespread infection in-theater. Other battlefield technologies include a soldier-portable hemostatic wound treatment system, capability to manufacture field-relevant pharmaceuticals in theater, and a rapid after-action review of field events as a diagnostic tool for improving the delivery of medical care and medical personnel protection. Improved medical imaging will be approached through new physical properties of cellular metabolic activities. New neural interface technologies will reliably extract information from the nervous system to enable control of the best robotic prosthetic-limb technology. To allow medical practitioners the capability to visualize and comprehend the complex relationships across patient data in the electronic medical record systems, technologies will be developed to assimilate and analyze large amounts of data and provide tools to make better-informed decisions for patient care. In the area of medical training, new simulation-based tools will rapidly teach increased competency in an open and scalable architecture to be used by all levels of medical personnel for basic and advanced training. Advanced information-based techniques will be developed to supplement warfighter healthcare and the diagnosis of post-traumatic stress disorder (PTSD) and mild traumatic brain injury (mTBI). This project will also pursue applied research efforts for dialysis-like therapeutics. FY 2015 Biomedical Technology program funding includes 114.8 million of base funding and 45.0 million of Ebola emergency funding.

B. Program Change Summary ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016 Base**	**FY 2016 OCO**	**FY 2016 Total**
Previous President's Budget	114.790	112.242	100.603	-	100.603
Current President's Budget	121.152	159.790	114.262	-	114.262
Total Adjustments	6.362	47.548	13.659	-	13.659
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	47.548			
• Congressional Directed Transfers	-	-			
• Reprogrammings	9.755	-			
• SBIR/STTR Transfer	-3.393	-			
• TotalOtherAdjustments	-	-	13.659	-	13.659

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2014	FY 2015
Project: BT-01: *BIOMEDICAL TECHNOLOGY*		
Congressional Add: *Ebola Response and Preparedness Congressional Add (Emergency Funds)*	-	45.000
Congressional Add: *Biomedical Congressional Add*	-	2.548
Congressional Add Subtotals for Project: BT-01	-	47.548
Congressional Add Totals for all Projects	-	47.548

Change Summary Explanation

FY 2014: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2015: Increase reflects congressional adds. The Ebola Response and Preparedness Congressional Add is non-OCO emergency funding.
FY 2016: Increase reflects expanded focus in brain and prosthetic interface systems research.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Autonomous Diagnostics to Enable Prevention and Therapeutics (ADEPT)	29.153	26.000	24.700

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 2014 Accomplishments:
- Demonstrated ability to manipulate the type of immune response induced by RNA-based vaccines.
- Demonstrated ability to target delivery of RNA-based vaccines to specific cell types.
- Developed novel methodologies to deliver nucleic acid constructs encoding one or hundreds of antibodies identified from immunized or convalescent patients.
- Demonstrated delivery of nucleic acids that transiently produce multiple antibodies.
- Performed quantitative comparison of room temperature assay methods appropriate for integration in devices for low-resourced settings.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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 2014	FY 2015	FY 2016
- Demonstrated initial component integration and defined performance metrics for advanced diagnostic device prototypes suitable for operations in remote clinic and low-resourced settings. ***FY 2015 Plans:*** - Demonstrate 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. - Investigate targeted delivery of nucleic acid constructs to specific cell types. - Demonstrate 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. - Develop designs for RNA-based vaccines to enable transition to human clinical trials. - Develop designs for initial diagnostic device prototypes, based on highest performing components. - Produce first-generation, integrated diagnostic prototypes designed for relevance to physician office, remote clinic, and low-resourced settings. - Measure quantitative performance of first-generation, integrated diagnostic device prototypes and determine modifications required for performance improvements. ***FY 2016 Plans:*** - 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. - Submit Investigational New Drug (IND) application for transient nucleic acid-based formats against infectious disease. - 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.			
Title: Dialysis-Like Therapeutics ***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.	20.000	19.492	6.073

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 2014 Accomplishments:*** - Integrated biocompatible high-flow fluid manipulation and intrinsic separation technologies into a breadboard device for the treatment of sepsis. - Used feedback from initial animal model testing to inform the development of an integrated device for additional safety and efficacy studies in a large-animal sepsis model. - Proceeded with regulatory approval process and initiated plan for investigational device exemption submission. ***FY 2015 Plans:*** - Manufacture a prototype device that integrates label-free separation technologies, high-flow fluidic architectures, and non-thrombogenic coatings for testing. - Evaluate the efficacy of the label-free separation technologies in a small-animal model. - Refine the prototype device design based on animal testing results to inform development of a standalone benchtop integrated device. - Establish 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. - Perform biocompatibility studies of each component of the device to ensure safety in the integrated system. ***FY 2016 Plans:*** - Perform safety and efficacy studies in a large-animal sepsis model. - Initiate regulatory approval submission package with safety and efficacy data.			
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	12.000	6.000	6.000

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 2014 Accomplishments:*** - Leveraged open source biomechanical model to iterate design. - Completed development of component technologies based on results of preliminary component technology reviews and government testing. - Initiated design of full Warrior Web system. ***FY 2015 Plans:*** - Conduct preliminary review of Warrior Web designs and refine approach as necessary. - Finalize open source biomechanical models to be leveraged for the Warrior Web system evaluation. - Mature design of Warrior Web system and continue parallel technology development. - Conduct 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. - Conduct final evaluation of prototype system through soldier tests in relevant military environments. - Coordinate military transition of the technology.			
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 or other therapies that can bypass and/or recover the neural functions underlying memory, which are often disrupted as a consequence of TBI. This program is leveraging research conducted under the Human Assisted Neural Devices effort in Program Element 0601117E, Project MED-01. ***FY 2014 Accomplishments:***	8.000	9.700	15.800

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Identified neural codes underlying optimal memory formation. - Optimized electrodes for chronic, indwelling recording and stimulation. ***FY 2015 Plans:*** - Identify commonalities of neural codes underlying memory formation. - Identify distinctions between neural codes underlying different classes of memories. - Identify expert memory codes for the formation of memory associations between pairs of elements (e.g., objects, locations, actions). - Develop portable computational device with integrated computational model of human memory formation. - Demonstrate 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 (e.g., objects, places, faces) and spatial and non-spatial associations. - Identify optimal stimulation parameters for improving spatial memory. - 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. - Design, develop and validate both external and implantable hardware and software systems for an integrated memory restoration system. - Demonstrate the ability for a computational model of memory to use long-term neurophysiological activity to predict and restore memory. - Submit initial, novel devices for regulatory approval.			
Title: Neuro-Adaptive Technology ***Description:*** Building upon technologies developed under the Military Medical Imaging program budgeted in this project, 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-	-	21.500	31.089

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 Plans:*** - Develop tests that activate key brain subnetworks for each functional domain. - Develop computer algorithms/programs to automatically merge elements of multimodal brain activity across time/space. - Create statistical computational models of brain activity and corresponding behavior to support the neurophysiology of new therapeutic systems. - Train decoders on a subset of domains and cross-validate on novel scan, record, and stimulate data. - Develop hardware interface stability, biocompatibility, and motion correction for recording neural activity. - Demonstrate three-dimensional, single-cell-resolution acquisition of real-time brain activity in large volumes of neural tissue. - Submit 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.			
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 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	-	10.550	18.800

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 Plans:*** - Develop and demonstrate advanced algorithms to control prosthetic limbs using signals extracted from commercially available or newly developed electrodes. - Develop and demonstrate micro-stimulation interface technologies that provide reliable signals into the peripheral and/or central nervous system for closed-loop prosthetic control. - Perform safety and efficacy testing of novel implantable interface technology which capture motor control signals and provide electrical sensory stimulation through the peripheral nervous system. - Demonstrate bench-top functionality of next-generation peripheral interface technology. - Develop 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. - Develop 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 government-furnished virtual prosthesis. - Perform safety and efficacy testing of integrated HAPTIX system 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. - Determine 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.			
Title: Performance Optimization in Complex Environments ***Description:*** The Performance Optimization in Complex Environments program focuses on leveraging advances in and integration of sensors, computation, analytics, and medicine 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 focus on developing the necessary models, analytical tools, interfaces, and input-output modalities 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 age, mental impairment, and physical injury, among	-	-	11.800

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
others. Research will also focus on understanding various forms of sensing and actuation to improve outcomes and how biofeedback over time can alter human physiology. Technologies developed through this program will provide a foundation of novel value propositions to the warfighter in terms of individual health, resilience, cognitive and physical effectiveness, and force multiplication. ***FY 2016 Plans:*** - Begin development of new algorithms for sensing and modeling of physiological and cognitive state. - Explore and identify primary sensing methods for reading biological signals. - Begin research on biological interfaces for enabling input-output of information. - Explore and study impact of various actuation mechanisms on physiological state and outcomes.			
Title: Tactical Biomedical Technologies ***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 intracavitary bleeding. A focus in this thrust is the co-development of a materials-based agent(s) and delivery mechanism capable of hemostasis and wound control for non-compressible hemorrhage in the abdominal space, regardless of wound geometry or location within that space. This thrust will also investigate 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 2014 Accomplishments:*** - At laboratory scale, designed continuous flow synthesis steps for the following Active Pharmaceutical Ingredients (APIs): Salbutamol, Ciprofloxacin, Azithromycin, Rufinamide, Etomidate, Nicardipine, and Neostigmine. - Engaged the Food and Drug Administration (FDA) for input on Process Analytical Technologies (PAT) and current Good Manufacturing Process (cGMP) for Diphenhydramine, Diazepam, Lidocaine, Fluoxetine, Ibuprofen, Atropine, and Doxycycline. - Performed in vivo demonstration of transcranial photocoagulation of intracranial vessels in porcine model. - Performed in vivo demonstration of photo-induced vasospasm in intracranial vessels in porcine model. - Designed and developed upstream and downstream components of miniaturized end-to-end manufacturing platform for protein therapeutics using cell-free and cell-based protein translation systems, including integration of protein expression and purification processes. ***FY 2015 Plans:***	13.321	12.000	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Develop novel continuous flow crystallizer, miniaturized reactors, and chemically compatible pumps for integration into a compact end-to-end manufacturing platform for the following APIs: Diphenhydramine, Diazepam, Lidocaine, Fluoxetine, Ibuprofen, Atropine, Doxycycline, Salbutamol, Ciprofloxacin, Azithromycin, Rufinamide, Etomidate, Nicardipine, and Neostigmine. - Demonstrate continuous flow synthesis, crystallization, and formulation for Salbutamol, Ciprofloxacin, Azithromycin, Rufinamide, Etomidate, Nicardipine, and Neostigmine, in an integrated manufacturing platform. - Engage the FDA for input on PAT and cGMP for Salbutamol, Ciprofloxacin, Azithromycin, Rufinamide, Etomidate, Nicardipine, and Neostigmine. - Develop novel cell-free protein synthesis techniques using miniaturized bioreactors and/or microfluidics technologies. - Demonstrate end-to-end manufacturing of two protein therapeutics in a miniaturized platform, including the integration of protein expression and purification processes. - Engage the FDA for input on PAT and cGMP for protein therapeutics. - Design end-to-end manufacturing process in a miniaturized and integrated platform for an additional four protein therapeutics. - Test 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.			
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 will provide capabilities to predict emerging threats and the evolution of resistance of pathogens to medical countermeasures. Pathogen Defeat focuses 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 2014 Accomplishments:*** - Predicted location of genetic mutation(s) responsible for failure of a monoclonal antibody to neutralize a virus. - Demonstrated that an in vitro drop microfluidics evolution platform can be used to rapidly evolve viruses at the single event level. - Began transition discussions on in vitro evolution platforms to increase preparedness for diseases like seasonal influenza, Dengue, and other emerging human pathogens. - Began development of a hand-held device for rapid identification of microbial organisms, including development of diagnostic panels to be integrated into a modular, single-use microfluidics card. - Explored constraints of pressures (antibodies, anti-virals) on viral evolution and effects on reassortment and recombination. ***FY 2015 Plans:*** - Test predictive capabilities of trajectories to clinical viral isolates in evolution platform. - Elucidate mechanisms to explain viral escape to different pressures. - Rapidly evolve virus strains in avian cells to select vaccine candidates with antigenic similarities.	20.678	7.000	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Perform objective field assessment of hand-held devices for microbial and viral pathogens for clinical and environmental testing.			
Title: Military Medical Imaging ***Description:*** The Military Medical Imaging thrust developed medical imaging capabilities to support military missions and operations. The emergence of advanced medical imaging includes newly recognized physical properties of biological tissue, metabolic pathways, or physiological function in order to produce an image of diagnostic utility and performance. The goal of this thrust was to develop new, portable spectroscopic techniques that can provide information for military medical use (e.g., analysis of traumatic brain injury) that is superior to that provided by an MRI. This need is ever increasing as researchers and scientists seek to better understand anatomical, functional, and cellular-level interactions. Finally, this thrust allowed safe, non-invasive to minimally invasive detection of microscopic and functional alterations within tissues and organs of a living organism at early stages of injury. The advanced development of these tools has provided a formidable arsenal of diagnostic tools for warfighter performance and care. ***FY 2014 Accomplishments:*** - Designed and fabricated blazed, stacked, diffractive x-ray optics for integration into a pre-clinical imaging prototype. - Designed and tested imaging and validation protocols for pre-clinical imaging prototype. - Identified candidate approaches for real-time analysis and monitoring of biological activity during performance of behavioral tasks. - Developed electrophysiological methods for simultaneous recording of multiple levels of abstraction in cortical/subcortical targets.	8.000	-	-
Title: Revolutionizing Prosthetics ***Description:*** The goal of this thrust was to radically improve the state of the art for upper limb prosthetics, moving them from crude devices with minimal capabilities to fully integrated and functional limb replacements. Current prosthetic technology generally provides only gross motor functions, with very crude approaches to control. This makes it difficult for wounded soldiers to re-acquire full functionality and return to military service if so desired. The advances required to provide fully functional limb replacements were achieved by an aggressive, milestone-driven program combining the talents of scientists from diverse areas including: medicine, neuroscience, orthopedics, engineering, materials science, control and information theory, mathematics, power, manufacturing, rehabilitation, psychology, and training. The results of this program radically improved the ability of combat amputees to return to normal function. ***FY 2014 Accomplishments:*** - Conducted pre-launch activities of non-invasively controlled prosthetic arm system. - Demonstrated brain control of bilateral prosthetic arms simultaneously.	10.000	-	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Incorporated design updates in prosthetic arm systems to improve reliability. - Continued human quadriplegic patient trials demonstrating longevity of cortical control.			
Accomplishments/Planned Programs Subtotals	121.152	112.242	114.262

	FY 2014	FY 2015
Congressional Add: Ebola Response and Preparedness Congressional Add (Emergency Funds) ***FY 2015 Plans:*** This program will speed 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. Planned research builds on earlier investments by DARPA exploring technologies to discover, optimize, and deliver antibodies as a means to provide fast-acting protection against infectious diseases. A key component of this program is 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. - Conduct dose escalation study for encoded Ebola vaccine. - Demonstrate rapid discovery of potent antibodies from human Ebola survivors. - Evaluate protective efficacy of encoded Ebola antibodies in small and/or large animal models. - Test protective efficacy of encoded Ebola vaccine in small and/or large animal models. - Validate cell-free production of nucleic acid-encoded antibody or vaccine formulations.	-	45.000
Congressional Add: Biomedical Congressional Add ***FY 2015 Plans:*** This effort will further the development of restorative products and technologies as alternatives to amputation.	-	2.548
Congressional Adds Subtotals	-	47.548

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

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F. Performance Metrics

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

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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	370.643	324.407	356.358	-	356.358	364.076	355.357	368.535	368.091	-	-
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	66.481	29.800	51.490	-	51.490	58.659	58.379	63.846	58.413	-	-
IT-03: *INFORMATION ASSURANCE AND SURVIVABILITY*	-	172.063	179.947	208.957	-	208.957	240.177	245.501	249.833	254.923	-	-
IT-04: *LANGUAGE TECHNOLOGY*	-	74.332	45.511	60.897	-	60.897	65.240	51.477	54.856	54.755	-	-
IT-05: *CYBER TECHNOLOGY*	-	57.767	69.149	35.014	-	35.014	-	-	-	-	-	-

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, embedded computing systems, and novel design tools for manufacturing of defense 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 Technology project will develop human language technologies to provide critical capabilities for a wide range of national security needs ranging from knowledge management to low-resource language understanding. This project develops technologies to automatically translate, collate, filter, synthesize, summarize, and present relevant information in timely and relevant forms. The Language Technology project is addressing these diverse requirements by developing core language processing technologies and integrating these technologies into operational prototypes suitable for use in the field.

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

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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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	399.597	334.407	339.844	-	339.844
Current President's Budget	370.643	324.407	356.358	-	356.358
Total Adjustments	-28.954	-10.000	16.514	-	16.514
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-10.000			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-17.142	-			
• SBIR/STTR Transfer	-11.812	-			
• TotalOtherAdjustments	-	-	16.514	-	16.514

Change Summary Explanation

FY 2014: Decrease reflects below threshold and omnibus reprogrammings and the SBIR/STTR transfer.
FY 2015: Decrease reflects congressional reduction.
FY 2016: Increase reflects initiation of new start programs in the High-Productivity, High-Performance Responsive Architectures project and expansion of the Low Resource Languages for Emergent Incidents (LORELEI) Technology effort.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	66.481	29.800	51.490	-	51.490	58.659	58.379	63.846	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. One of the major challenges currently facing the DoD is the prohibitively high cost, time, and expertise required to build large complex software systems. 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 2014	FY 2015	FY 2016
Title: Power Efficiency Revolution For Embedded Computing Technologies (PERFECT)	41.253	23.800	23.800
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 data placement to provide the required embedded system processing power efficiency. ***FY 2014 Accomplishments:*** - Developed an analytical modeling framework for fundamental design trade-off analysis and documentation for local resilience and power optimizations and global optimization methodologies and techniques. Included delivery of initial IBM layered analytical framework addressing concept specification of cross-layer resiliency optimization methodologies, power performance/optimal voltage selection, and throughput performance that developed fundamental trade-off capabilities for power, performance, and			

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
reliability for a given embedded system and application space. Included release of improved generation of UC Berkeley Chisel 2.0 hardware construction language for design exploration and generation. - Established algorithmic analysis and design methodologies for power efficient and resilient processing. Included first practical implementation of communication-avoiding rectangular matrix multiplication using a communication-optimal recursive algorithm, outperforming the Intel Math Kernel Library hand-optimized implementation by up to 10x. - Defined power efficient, heterogeneous, highly concurrent conceptual architectural design approaches. Test and verification team evaluation report of results to date confirmed collective capabilities to obtain program goal of 75 GFLOPS/W embedded system performance. The evaluation was based on design concepts for power efficient architecture implementations. - Defined and evaluated the impact of 3D approaches for power efficient processing, including design and simulation of a 3D-stacked Logic-in-Memory (LiM) system architecture to accelerate the processing of sparse matrix data. Simulation results outperform state-of-the-art server and GPU systems by 100x in performance and 1000x in energy efficiency. ***FY 2015 Plans:*** - Incorporate test chip results - circuit, architecture, communication, power management, 3D - for design optimization and simulation refinement for continuing architectural development efforts. - Develop compiler algorithms supporting communication-avoiding optimization, concepts for optimizing parallel codes and language-based auto-tuning. - Deliver 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 release new hardware description language and modeling/simulation infrastructure incorporating the evaluation and development of algorithms, specializers, hardware architectures, and resiliency techniques. ***FY 2016 Plans:*** - Identify and select implementation and transition targets and establish collective PERFECT teams technologies to support target requirements. - Extend device models to include different physical device scattering mechanisms including acoustic phonon scattering and the impact of quantum mechanical effects on device level characteristics and provide updated device models and libraries of logic gates and memory bit cells incorporating optimization methodologies for super threshold and near threshold operation. - Complete hardware design evaluations for: low voltage on-chip RAM; adaptive clocking; low-energy signaling; energy-efficient architecture hierarchies; application-specific processing; specialized DRAM architectures; diverse heterogeneous architectures. - Develop the language constructs and compiler technology supporting the implementation of communication avoiding algorithms and the optimizing and managing of processor heterogeneity, concurrency, data locality, and language based autotuning. - Implement modeling and evaluation environment integration combining separate optimization tools for power, communication avoidance, and resiliency to provide detailed trade-off analysis results and insight and demonstrate on a range of (1) ISR			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
kernels (2) PERFECT hardware targets, and (3) problem instance sizes to support 20X power savings incorporating resiliency requirements relative to classical compilers on representative PERFECT hardware architectures.			
Title: Complexity Management Hardware* ***Description:*** *Formerly Cortical Processor 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. In this project, we 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 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 applied research aspects of this program will look at the 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 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 for the program is budgeted in PE 0601101E, Project CCS-02. ***FY 2015 Plans:*** - Design complexity management processor algorithm and benchmark tests for object recognition in still images and action recognition in video. - Demonstrate critical features of algorithm including ability to learn and adapt while operating. - Quantify 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.	-	6.000	12.190

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Create initial hardware verification of concepts for both sparse and hardware demonstrations.			
Title: Scalable Optical Nodes for Networked Edge Traversal (SONNET) ***Description:*** 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 demand on the processors is low, resulting in extremely low compute efficiency. Computationally, graph analysis is characterized by many short, random accesses to memory which is inefficient on current systems that are optimized for regular, predictable access. The SONNET program will build a silicon photonics-based graph processor that will perform graph analysis on Terabytes (TBs) of data with performance comparable to peta-scale supercomputers in a significantly smaller size, weight, and power (SWAP) envelope. SONNET will optimize the design of the graph processor by co-designing processor and photonic hardware, and the computer and network architectures to exploit the high bandwidth provided by silicon photonics. SONNET will demonstrate a scalable, power efficient prototype of such a graph processor and quantify performance for DoD-relevant applications. The performance, efficiency, and size will be transformational for big data analytics and enable real-time analysis on dynamic graphs in the fields of cyber security, threat detection, and numerous others. This program will explore the efficient processing of local information using stacked memory and integrated circuits specially made for specific tasks, as well as the efficient transfer of data between local information processors. The SONNET program will optimize the design of a graph processor and design and demonstrate high performance processor cores to accelerate graph primitives and photonic hardware required for high bandwidth, low diameter photonic networks. The program will design and evaluate a Graph processor capable of analyzing large data sets relevant to future DoD requirements. This program has advanced technology development efforts funded in PE 0603760E, CCC-02. ***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. - Design corresponding hardware, e.g. processor cores, to optimize performance for high bandwidth photonic networks. - Design algorithms to execute DoD problems on a SONNET system and estimate system performance.	-	-	3.500
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	-	-	12.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
potential consequences such as reverse engineering, theft of U.S. intellectual property, and non-authorized use of these electronic components in adversary defense systems. New applied research technology enablement will be developed in the Electronics Globalization program to provide the desired responses such as special chip packaging, on-board infrastructures, process modifications, and the use of Supply Chain Hardware Intercepts for Electronics Defense (SHIELD)-monitor dielet. Applied research will focus on the engineering of unique devices and circuit technologies. Concepts and design flows which enable trust in an untrusted environment will be developed and applied. Basic research for the program is budgeted in PE 0601101E, Project ES-01. ***FY 2016 Plans:*** - Develop a specific CONOP using the proposed structure, and identifying key enablers needed to realize it. - Model designs such as encryption engines used to enable authorized chip operation. - Create and model process module modifications for a standard fab gate recipe that result in desired behaviors. - Demonstrate proof-of-concept of the ability of SHIELD-like devices to selectively authorize chip operation. - Complete a high level design of piggyback chips which can monitor and alter instruction execution of the host component.			
Title: Instant Foundry Adaptive Through Bits (iFAB) ***Description:*** Instant Foundry Adaptive Through Bits (iFAB), provided the groundwork for the development of a foundry-style manufacturing capability--taking as input a verified system design--capable of rapid reconfiguration to accommodate a wide range of design variability and specifically targeted at the fabrication of military ground vehicles. The iFAB vision was to move away from wrapping a capital-intensive manufacturing facility around a single defense product, and toward the creation of a flexible, programmable, potentially distributed production capability able to accommodate a wide range of systems and system variants with extremely rapid reconfiguration timescales. The specific goals of the iFAB program were to rapidly design and configure manufacturing capabilities to support the fabrication of a wide array of infantry fighting vehicle models and variants. Once a given design was developed and verified, iFAB took the formal design representation and automatically configured a digitally-programmable manufacturing facility, including the selection of participating manufacturing facilities and equipment, the sequencing of the product flow and production steps, and the generation of computer-numerically-controlled (CNC) machine instruction sets as well as human instructions and training modules. iFAB was mostly an information architecture. Only the final assembly capability needed to be co-located under a single roof in anything resembling a conventional fabrication facility; the rest of iFAB could be geographically distributed and can extend across corporate and industrial boundaries, united only by a common model architecture and certain rules of behavior and business practices. The final assembly node of the iFAB Foundry was the Joint Manufacturing and Technology Center (JMTC) at the Rock Island Arsenal (RIA).	9.734	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
FY 2014 Accomplishments: - Completed the manufacture and assembly of the winning drivetrain and mobility subsystem design from the first FANG Challenge. - Provided manufacturability feedback to the META design process in support of the tool validation testing. - Transitioned iFAB software tool suite and associated technology to the Digital Manufacturing and Design Innovation Institute (DMDII) through the co-funded research and formal technology transition activities for industry use. - Transitioned all physical infrastructure for the iFAB Foundry final assembly node at RIA to JMTC.			
Title: META ***Description:*** The goal of the META program was to develop novel design flows, tools, and processes to enable a significant improvement in the ability to design complex defense systems that could be verified by virtual testing. The program sought to develop a design representation from which system designs can quickly be assembled and their correctness verified with a high degree of certainty. Such a "fab-less" design approach was complemented by a foundry-style manufacturing capability, consisting of a factory capable of rapid reconfiguration between a large number of products and product variants through bitstream re-programmability, with minimal or no resultant learning curve effects. Together, the fab-less design and foundry-style manufacturing capability was anticipated to yield substantial---by a factor of five ---compression in the time to develop and field complex defense and aerospace systems. ***FY 2014 Accomplishments:*** - Concluded expanded development of META tool suite to include qualitative and relational abstraction modeling, probabilistic certificate of correctness calculations, complexity metric evaluation, non-linear Partial Differential Equation (PDE) analysis, and cyber design evaluation. - Conducted preliminary developmental Beta testing and integrated demonstration testing for the expanded META tool suite including expanded capability features. - Conducted META tool transition activity to commercial Product Lifecycle Management (PLM) tool suites. - Transitioned META software tool suite and associated technology to the Digital Manufacturing and Design Innovation Institute (DMDII) through the use of co-funded research and formal technology transition activities for industry use. - Further expanded META Software tool suite accessibility by developing a web-based solution for the Generic Modeling Environment (GME).	15.494	-	-
Accomplishments/Planned Programs Subtotals	66.481	29.800	51.490

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C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
IT-03: *INFORMATION ASSURANCE AND SURVIVABILITY*	-	172.063	179.947	208.957	-	208.957	240.177	245.501	249.833	254.923	-	-

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 DoD information systems to operate correctly and continuously even under attack. Technologies developed under 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)

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: High Assurance Cyber Military Systems	23.889	24.000	34.500

Description: The High Assurance Cyber Military Systems program will develop and demonstrate 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, personal digital assistants, 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 2014 Accomplishments:
- Demonstrated compositionality, which is the ability to construct high assurance systems out of high assurance components.
- Extended the core high-assurance embedded operating system with additional functionality, including automatically generated device drivers and communication protocols.
- Automatically synthesized correct-by-construction control systems from high-level specifications.

FY 2015 Plans:

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Formally verify full functional correctness for the extended core operating system and the automatically synthesized control systems for selected vehicles. - Demonstrate required security properties that follow from correctness for the extended core operating system and the automatically synthesized control systems. - Perform static and dynamic assessments after modifications are made on militarily-relevant vehicles to evaluate the effectiveness of the synthesis and formal methods tools. ***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 ground vehicle, and an American-built car. - Demonstrate machine-tracked assurance cases for at least six system-wide security properties on targeted vehicles. - Evaluate the effectiveness of approaches by having a red team conduct penetration-testing exercises on the targeted vehicles. - Increase the level of automation of proof generation in theorem provers.			
Title: Vetting Commodity Computing Systems for the DoD (VET) ***Description:*** The Vetting Commodity Computing Systems for the DoD (VET) program will develop 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 also enable the detection of software and firmware defects and vulnerabilities that can facilitate adversary attack. ***FY 2014 Accomplishments:*** - Developed relevant application programming interfaces and defined formal semantics for the programming languages to be analyzed. - Produced initial prototype attack scenario generation, program analysis, and diagnostic tools. - Produced initial set of challenge programs for use in a competitive evaluation. - Performed a competitive engagement between research and adversarial challenge performers to produce measurements of research progress against program metrics. ***FY 2015 Plans:*** - Improve the effectiveness of prototype tools, in particular by reducing the rates of false alarms and missed detections, through further competitive engagements. - Expand the set of challenge programs to explore more complex forms of malicious hidden functionality including race conditions, information leakage, and defective encryption.	17.954	21.760	30.325

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Replace initial experimental platforms with more complex devices that are more operationally representative. ***FY 2016 Plans:*** - Use measurements against the program metrics, probabilities of false and missed detection and human analysis time, to identify the 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.			
Title: Supply Chain Hardware Intercepts for Electronics Defense (SHIELD) ***Description:*** Counterfeit electronic parts are becoming ubiquitous, 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 limitations. 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 methods are specific to a manufacturer's component and as such address only those issues deemed critical to that manufacturer. Some methods can be circumvented, or require slow, expensive, off-site forensic analysis to verify authenticity. The Supply Chain Hardware Intercepts for Electronics Defense (SHIELD) program, leveraging and expanding on previous activities in the IRIS program, will develop a technology capable of confirming, at any time, the authenticity of once-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 microscopic-size dielet embedded in the electronic component packaging will be inductively powered and scanned by an authentication induction coil brought into very close proximity to the packaged chip, thus allowing for verification of chip identity. ***FY 2014 Accomplishments:*** - Defined dielet power consumption and transaction timing specifications. - Defined physical form factor for dielet. - Defined concept of operation for dielet to server communications. - Selected target encryption standard for dielet. ***FY 2015 Plans:*** - Develop behavioral models for SHIELD dielet performance	5.000	17.250	27.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Establish a power budget for all dielet electronics. - Define server communication protocols, encryption scheme, and network architectures. - Develop proof of concept for sensor, power and communications technologies. - Design surrogate dielet for package tests. - Define process modifications needed to accommodate SHIELD insertions. - Develop technologies to allow secure key and ID storage and prevent tampering with the dielet. - Design a compact encryption engine that enables a very small, low power, and low-cost dielet. - Simulate and prototype dielet package-insertion techniques for placing SHIELD dielet on product. ***FY 2016 Plans:*** - Build prototype hardware. - Develop infrastructure needed to execute SHIELD concept of operations. - Design and build network appliance needed for remote interrogation of components.			
Title: Active Cyber Defense (ACD) ***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 2014 Accomplishments:*** - Developed techniques for countering adversary cyber tradecraft and implemented early prototype software applications. - Developed detailed system designs and design documentation. - Finalized test plans and performed initial evaluations of active cyber defense prototypes in risk reduction assessments. - Provided capabilities to support exercises with transition partners and to perform preliminary operational assessments of technologies. ***FY 2015 Plans:*** - Complete development of system components. - Begin integration of technologies into complete prototype platforms. - Test integrated capabilities. ***FY 2016 Plans:***	12.500	13.828	13.914

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- 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: Mission-oriented Resilient Clouds (MRC) ***Description:*** The Mission-oriented Resilient Clouds (MRC) program will create 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 will address this risk by creating advanced network protocols and new approaches to computing in potentially compromised distributed environments. Particular attention will be focused on adapting defenses and allocating resources dynamically in response to attacks and compromises. MRC will create new approaches to measuring trust, reaching consensus in compromised environments, and allocating 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 2014 Accomplishments:*** - Produced a cloud task allocation system that maximizes mission effectiveness in the context of current system loads without significantly increasing hardware costs. - Implemented and evaluated a packet-level monitoring tool that enables flexible, on-the-fly path analysis for network troubleshooting and attack detection. - Validated and deployed an intrusion-tolerant overlay network for cloud monitoring and control. - Transitioned a minimalist library microkernel into open source and commercial hypervisor products. - Evaluated a network path diversity research product for potential transition into USPACOM distributed computing environments. ***FY 2015 Plans:*** - Demonstrate automated construction of diverse, redundant network flow paths that maximize communication resilience in clouds. - Evaluate 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. - Develop and demonstrate 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. - Insert MRC technologies into USPACOM distributed computing environments. - Evaluate technologies in Defense Information Systems Agency (DISA) testbeds to facilitate transitions into DoD clouds. ***FY 2016 Plans:*** - Demonstrate correct, disruption-free upgrading of software defined networking controllers in live networks.	21.571	15.892	14.627

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
- Complete transition of one or more technologies into operational use by USPACOM and DISA.			
Title: Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT)* ***Description:*** *Previously Secure Distributed Dynamic Computing (SDDC) funded in PE 0603766E, Project NET-01 The Edge-Directed Cyber Technologies for Reliable Mission Communication (EdgeCT) program will enable reliable communications for military forces that operate in disrupted/disadvantaged, intermittent, high-latency environments. The program will create 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 work-arounds (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 Plans:*** - Develop a host-based architecture for reliable communications in disrupted/disadvantaged, intermittent, high-latency military environments. - Develop techniques to sense and respond rapidly to network failures and attacks by dynamically adapting protocols utilized to exchange packets among hosts. - Explore modes of user interaction and system concepts of operation with one or more operational commands. ***FY 2016 Plans:*** - Initiate development of software prototypes suitable for laboratory experimentation with operational commands. - Develop work-arounds (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. - Bring software prototypes to an initial field experiment in collaboration with an operational command.	-	11.000	22.000
Title: Cyber Fault-tolerant Attack Recovery (CFAR) ***Description:*** Building upon previous work in the Clean-slate design of Resilient, Adaptive, Secure Hosts (CRASH) program, the Cyber Fault-tolerant Attack Recovery (CFAR) program will develop 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	-	10.000	20.149

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 Plans:*** - Formulate novel architectures that achieve cyber fault-tolerance with commodity computing technologies without requiring changes to the system concept of operations. - Develop techniques for detecting differences across functionally replicated systems. - Develop novel variants that guarantee differences in behavior under attack. ***FY 2016 Plans:*** - 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.			
Title: Adaptable Information Access and Control (AIAC) ***Description:*** The Adaptable Information Access and Control (AIAC) program will create the capability to dynamically, flexibly, and securely share highly selective information across enterprise boundaries. In the civilian sphere, there is a recognized need for technologies that limit the sharing of information between commercial entities and U.S. government agencies to the greatest extent possible consistent with national security requirements. Similarly, the U.S. military is increasingly involved in humanitarian operations that require highly selective sharing of data with a heterogeneous mix of allies, coalition partners, and other stakeholders. AIAC will create confidentiality, privacy, multi-level security, discretionary access control, and policy engine technologies to allow tailored access to specific data and analytic results but not an entire database/file system/corpus. AIAC is timely due to recent progress on cryptographic techniques such as homomorphic encryption, secure multiparty computation, and differential privacy. Additional technologies that will be developed and incorporated include automated policy-driven releasability assessment and redaction, tactical obfuscation, and time-limited-access controls. The program will address the diverse and stringent legal and ethical requirements related to security, privacy, authentication, authorization, auditing, monitoring, access, and control encountered in both civilian and military environments. To facilitate deployment, AIAC 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.	-	7.093	17.600

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
FY 2015 Plans: - Formulate access control schemes appropriate for diverse civilian, intelligence, law enforcement, and coalition use cases with particular focus on privacy-preserving analytics. - Architect an access control policy engine for seamless interoperability with common computing and networking infrastructure software. - Create technologies for confidentiality, privacy, multi-level security, discretionary access controls, automated policy-driven releasability assessment and redaction, tactical obfuscation, computing on encrypted data, and time-limited-access controls. ***FY 2016 Plans:*** - Implement access control software prototypes with flexibility adequate to support diverse civilian, intelligence, law enforcement, and coalition use cases and with scalability adequate for big data applications. - Develop an access control policy engine and demonstrate interoperability with common cloud computing and software-defined networking infrastructure and services as appropriate. - Evaluate and refine technologies for confidentiality, privacy, multi-level security, discretionary access controls, automated policy-driven releasability assessment and redaction, tactical obfuscation, computing on encrypted data, and time-limited-access controls.			
Title: Protecting Cyber Physical Infrastructure (PCPI) ***Description:*** * Formerly Protecting Cyber Physical Systems (PCPS) The Protecting Cyber Physical Infrastructure (PCPI) program will create new technologies for ensuring the availability and integrity of critical U.S. cyber-physical infrastructure. The near-ubiquitous use of computers to monitor and control U.S. civilian and military critical infrastructure and the dependence of our society on electric power, clean water, waste processing, petroleum refining, chemical production, and other utilities/industries make this a national security issue. PCPI will develop technologies to monitor heterogeneous distributed control system networks, detect anomalies that require rapid assessment, and mitigate sensor spoofing and denial of service attacks. Hardware-in-the-loop simulation techniques will be developed to enable the discovery of emergent vulnerabilities and the development and optimization of mitigation strategies. This will include understanding the potential role of electric power markets in propagating or damping power grid anomalies. PCPI technologies will transition to military installations and commercial industry. ***FY 2015 Plans:*** - Create a hardware-in-the-loop simulation capability to enable the discovery of emergent vulnerabilities and the development and optimization of mitigation strategies.	-	7.525	17.513

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Formulate resilient architectures for real-time monitoring, analysis, and assessment of distributed industrial control systems and physical infrastructure. - Investigate 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:*** - Develop technologies to monitor heterogeneous distributed industrial control system networks, detect anomalies that require rapid assessment, and mitigate sensor spoofing and denial of service attacks. - 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. - Explore defensive measures/counter-measures that can mitigate/thwart a coordinated cyber attack on national critical infrastructure.			
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. Principal funding for this effort is 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 Plans:*** - Create a robust competition infrastructure as 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.	-	6.233	11.329
Title: Clean-slate design of Resilient, Adaptive, Secure Hosts (CRASH)	19.626	11.182	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Description: The Clean-slate design of Resilient, Adaptive, Secure Hosts (CRASH) program will develop 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 will develop mechanisms at the hardware and operating system level that eliminate known vulnerabilities exploited by attackers. However, because novel attacks will be developed, CRASH will also develop software techniques that allow a computer system to defend itself, to maintain its capabilities, and even heal itself. Finally, biological systems show that diversity is an effective population defense; CRASH will develop techniques that make each computer system appear unique to the attacker and allow each system to change over time. ***FY 2014 Accomplishments:*** - Completed the implementation of three novel, secure processors, developed the associated security extensions to one operating system, and subjected each to independent red-team assessment. - Demonstrated the capability to wrap integrated defense software and protect it from cyber attacks launched by an independent red team. - Demonstrated the ability of two or more complete systems to block, survive, and recover from multiple attacks and automatically repair vulnerabilities. - Developed and implemented multiple technologies for adding diversity to applications and assessed the impacts of these technologies on security and performance. - Automatically produced diverse instantiations of one complete operating system and multiple large applications for multiple operating systems. ***FY 2015 Plans:*** - Deliver a hardened web server and browser that enable the creation of secure web applications from untrusted code. - Demonstrate policy-based application monitoring and hardware-assisted self-healing of multiple applications. - Demonstrate hardware-based detection of malicious software.			
Title: Rapid Software Development using Binary Components (RAPID) ***Description:*** The Rapid Software Development using Binary Components (RAPID) program will develop 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 research for the program is budgeted in PE 0603760E, Project CCC-04.	8.198	10.396	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
FY 2014 Accomplishments: - Fully integrated technologies into a single architecture and standardized interfaces to enable partners to interoperate with the system. - Developed a single user interface that combines technical area views for monitoring system performance with a constructive interface for specifying desired products. ***FY 2015 Plans:*** - Develop new software component reuse capabilities to extend application performance to a wider range of realistic scenarios and enable an expanded concept of operations. - Implement new capabilities in modules designed to interoperate seamlessly with deployed RAPID prototype systems. - Integrate new modules into prototype RAPID systems deployed at transition partner sites and support initial operations.			
Title: Anomaly Detection at Multiple Scales (ADAMS) ***Description:*** The Anomaly Detection at Multiple Scales (ADAMS) program will develop and apply algorithms for detecting anomalous, threat-related behavior of systems, individuals, and groups over hours, days, months, and years. ADAMS will develop flexible, scalable, and highly interactive approaches to extracting actionable information from information system log files, sensors, and other instrumentation. ADAMS will integrate these anomaly detection algorithms to produce adaptable systems for timely insider threat detection. ***FY 2014 Accomplishments:*** - Created the capability to incorporate direct user feedback to improve coverage of threat types. - Developed and implemented technology that is adaptable to a wide variety of organizational structures, workflows, and data sources. - Developed techniques to provide the evidence needed to initiate focused response activities. - Developed two integrated prototype anomaly/threat detection systems suitable for rapid deployment in an operational environment. ***FY 2015 Plans:*** - Develop and implement technology to capture analyst expertise for assessing and explaining detected anomalies and incorporate such user feedback in decision loops for operators without highly specialized computer science knowledge. - Harden prototype and obtain DoD Information Assurance Certification and Accreditation Process approval for use on military networks. - Conduct and evaluate initial prototype in a large scale environment with operational partners.	15.272	7.000	-
Title: Active Authentication	13.100	7.025	-

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
Description: The Active Authentication program will develop more effective user identification and authentication technologies. Current authentication approaches are typically based on long, complex passwords and incorporate no mechanism to verify the user originally authenticated is the user still in control of the session. The Active Authentication program will address 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 will integrate multiple biometric modalities to create an authentication system that is accurate, robust, and transparent to the user. ***FY 2014 Accomplishments:*** - Demonstrated enhanced authentication using multiple biometrics representing complementary aspects of the individual. - Evaluated the level of confidence that is achievable using multiple advanced authentication mechanisms and quantified the resulting level of security using red teaming and other techniques. - Prototyped an authentication platform suitable for DoD use in collaboration with potential transition sponsors. - Initiated development of multiple authentication biometrics suitable for deployment on mobile hardware for potential use by the DoD. ***FY 2015 Plans:*** - Demonstrate multiple authentication biometrics suitable for deployment on mobile hardware for potential use by the DoD. - Prove flexibility of underlying prototype platform by creating an additional authentication platform suitable for DoD. - Prototype an authentication platform suitable for use on mobile hardware in collaboration with potential transition sponsors.			
Title: Safer Warfighter Computing (SAFER) ***Description:*** The Safer Warfighter Computing (SAFER) program is creating a technology base for assured and trustworthy Internet communications and computation, particularly in untrustworthy and adversarial environments. SAFER creates automated processes and technologies to enable military users to send and receive content on the Internet, utilizing commercially available hardware and software, in ways that avoid efforts to deny, locate, or corrupt communications. SAFER is also developing technology for performing computations on encrypted data without decrypting it first through fully homomorphic encryption and interactive, secure multi-party computation schemes. This will enable, for example, the capability to encrypt queries and compute an encrypted search result without decrypting the query. This technology will advance the capability to run programs on untrusted hardware while keeping programs, data, and results encrypted and confidential. This mitigates the important aspect of supply chain compromise. ***FY 2014 Accomplishments:*** - Improved software performance in fully homomorphic encryption, garbled-circuit secure multiparty computation, and secret-sharing secure multiparty computation, and performed independent benchmarks.	15.150	4.066	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Demonstrated an additional two orders of magnitude improvement in the performance of fully homomorphic encryption. - Refined field programmable gate array implementation of fully homomorphic encryption to yield a further order of magnitude performance improvement over optimized software implementation. - Demonstrated safe, encrypted Internet communications application: secure Voice over Internet Protocol (VOIP) teleconferencing. ***FY 2015 Plans:*** - Develop improved decoy routing, parallelized group messaging, dynamic traffic camouflage, and rendezvous strategy technologies. - Further optimize field programmable gate array and software implementations of fully homomorphic encryption to double performance over prior implementations. - Conduct the final independent, adversarial assessment of the effectiveness of technologies to prevent communication localization and detection, including newly developed adversarial techniques.			
Title: Integrated Cyber Analysis System (ICAS) ***Description:*** The Integrated Cyber Analysis System (ICAS) program will develop 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 will develop technologies to 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 2014 Accomplishments:*** - Developed a multi-tiered approach to device identification and information extraction by transcoding Simple Protocol and Resource description framework Query Language (SPARQL). - Developed SQL transcoding support to enable Relational Database Management System (RDBMS) information extraction. - Conducted initial demonstrations of core technologies including automatic indexing of data sources, common language integration, and reasoning across federated databases. ***FY 2015 Plans:*** - Develop and implement algorithms for automatically identifying and quantifying specific security risks on enterprise networks. - Conduct initial technology demonstrations including automatic indexing of data sources, common language integration, and reasoning across federated databases. - Integrate, evaluate, and optimize algorithms via testing against attacks/persistent threats provided by transition partners.	10.000	3.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Complete fully functional beta versions of the applications with operational stability suitable for testing at transition partner locations.			
Title: Logan ***Description:*** The Logan program will provide DoD enhanced capabilities to conduct Computer Network Attack (CNA). Techniques will be developed to disrupt and degrade adversary information systems and network operations, with particular interest in techniques likely to be robust to adversary countermeasure strategies. ***FY 2014 Accomplishments:*** - Automated and tested prototypes in conjunction with transition partner. - Optimized and hardened prototypes and initiated transition. ***FY 2015 Plans:*** - Transition automated prototype system.	8.803	2.697	-
Title: Integrity and Reliability of Integrated CircuitS (IRIS) ***Description:*** Integrated circuits (ICs) are core components of most electronic systems developed for the Department of Defense. However, the DoD consumes a very small percentage of the total IC production in the world. As a result of the globalization of the IC marketplace, much of the advanced IC production has moved to offshore foundries, and these parts make up the majority of ICs used in today's military systems. Without the ability to influence and regulate the off-shore fabrication of ICs, there is a risk that parts acquired for DoD systems may not meet stated specifications for performance and reliability. This risk increases considerably with the proliferation of counterfeit ICs in the marketplace, as well as the potential for the introduction of malicious circuits into a design. The Integrity and Reliability of Integrated CircuitS (IRIS) program developed techniques that will provide electronic system developers the ability to validate the function of digital, analog and mixed-signal ICs non-destructively, given limited data about the chip's detailed design specifications. These techniques included advanced imaging for identification of functional elements in deep sub-micrometer Complementary Metal-Oxide Semiconductor (CMOS) circuits, as well as computational methods to deal with the extremely difficult problem of determining device connectivity. Finally, the IRIS program developed innovative methods to determine the reliability of an IC by testing a limited number of samples. The current understanding of IC aging mechanisms, including negative bias temperature instability (NBTI), hot carrier injection (HCI), time-dependent dielectric breakdown (TDDB) and electromigration (EM) was leveraged to develop unique diagnostic test techniques.	1.000	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
FY 2014 Accomplishments: - Exercised completed methods for non-destructive imaging, circuit extraction and functional derivation. - Demonstrated methods for reliability analysis for improved accuracy, functionality and efficacy. - Combined analysis methods for imaging, circuit extraction and reliability modeling to identify anomalies on an integrated circuit test article, and to determine the impact of those anomalies on the reliability of the test article. - Transitioned technology to the Navy and the Air Force Research Lab for deployment in existing programs to analyze circuits for counterfeit issues. - Completed testing and evaluation of performers and test chips by government virtual lab highlighting advancements in program closeout and gaps to be addressed.			
Accomplishments/Planned Programs Subtotals	172.063	179.947	208.957

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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

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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
IT-04: *LANGUAGE TECHNOLOGY*	-	74.332	45.511	60.897	-	60.897	65.240	51.477	54.856	54.755	-	-

A. Mission Description and Budget Item Justification

The Language Technology project will develop human language technologies to provide critical capabilities for a wide range of national security needs ranging from knowledge management to low-resource language understanding. Foreign-language news broadcasts, web-posted content, and foreign-language hard-copy documents could provide insights regarding regional and local events, attitudes and activities, if there was a system that could automatically process large volumes of speech and text in multiple languages obtained through a variety of means. The project develops technologies to automatically translate, collate, filter, synthesize, summarize, and present relevant information in timely and relevant forms. In addition, current U.S. military operations often require warfighters on the ground to understand speech and text in foreign languages for which there may be no available linguists. The Language Technology project is addressing these diverse requirements by developing core language processing technologies and integrating these technologies into operational prototypes suitable for use in the field.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Deep Exploration and Filtering of Text (DEFT) ***Description:*** The Deep Exploration and Filtering of Text (DEFT) program will 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 completely free-text or semi-structured reports, messages, documents, or databases. DEFT will extract knowledge at scale for open source intelligence and threat analysis. Planned transition partners include the intelligence community and operational commands. ***FY 2014 Accomplishments:*** - Developed initial methods and algorithms for reasoning about both explicitly and implicitly expressed opinions and beliefs, for extracting causal knowledge, and for finding implicit meaning based on anomalous usages and disfluencies in a document or set of documents. - Conducted performance evaluations on data sets related to event representation and inference. - Expanded capabilities to additional application problems and domains such as target information augmentation in collaboration with end-users.	28.369	28.333	30.223

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Demonstrated feasibility of deep extraction and filtering for selected end-user applications and transitioned initial sets of algorithms to the intelligence community and a Combatant Command. ***FY 2015 Plans:*** - Develop technology for extracting belief, sentiment, and intent; for representing geo-spatial features and temporal events; and for inference and alerting from a set of documents. - Integrate multiple complementary algorithms into a comprehensive and consistent functional suite to support end-user workflows and problems. - Increase algorithm development focus towards knowledge base representation in preparation for embedding algorithms in workflows to enable reasoning and downstream analysis. - Extend algorithms to additional foreign languages such as Spanish and Chinese. - Conduct performance evaluations on data sets related to event representation, anomaly detection, and knowledge base population. - Transition algorithm suites and conduct effectiveness assessments at end-user sites. - Enlarge the scope of event coverage to include increasingly complex events. ***FY 2016 Plans:*** - Improve algorithm performance on current functions and expand to new functions such as extending currently single-document algorithms to function across documents. - Optimize algorithm coverage and improve performance for foreign languages such as Spanish and Chinese. - Join and optimize combined output of algorithms focused on different tasks such as belief and sentiment extraction, event argument and attribute identification, and relation mapping. - Transition system-level prototype to end-user site for effectiveness assessment. - Refine areas of focus based on results of transition site evaluations and open evaluation performance.			
Title: Robust Automatic Translation 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 2014 Accomplishments:***	4.850	6.178	8.500

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Evaluated performance showing substantial progress on noisy and degraded speech signals from the program-generated data corpus. - Collected and annotated classified field data for training and testing. - Evaluated technologies on field-collected data and tested the system for in-the-field adaptation. - Obtained real world data from operational users and performed testing on site at the user location. - Established relationships with various DoD and intelligence community agencies as potential transition partners. ***FY 2015 Plans:*** - Develop new methods for field adaptations which include lightly supervised and unsupervised adaptation of the algorithms to new channels and environments. - Develop methods for coping with extraneous signals found in field data. - Develop techniques to significantly reduce the amount of data from hours to minutes for adapting algorithms to new channels. - Produce 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. - Integrate technologies in transition partner platforms, adjusting systems to fit partner needs. - Evaluate technologies on specialized operational scenarios.			
Title: Low Resource Languages for Emergent Incidents (LORELEI)* ***Description:*** *Formerly Foreign Language Rapid Response (FLRR) The Low Resource Languages for Emergent Incidents (LORELEI) program will develop the capability to rapidly construct machine translation and other human language technologies 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 as a result systems exist only for languages in widespread use and in high demand. The goal of the LORELEI program is to dramatically advance the state of computational linguistics and human language technology to enable rapid, low-cost development of language processing capabilities for low-resource languages. To achieve this LORELEI will eliminate reliance on huge, manually-translated, manually-transcribed, or manually-annotated corpora and instead will leverage language-universal resources, project from related-language resources, and fully exploit a broad range of language-specific resources. These capabilities will be exercised to provide situational awareness based on information from any language, in support of emergent	-	11.000	22.174

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
missions such as humanitarian assistance/disaster relief, terrorist attack response, peacekeeping, and infectious disease response. ***FY 2015 Plans:*** - Develop techniques for quantifying the linguistic similarity of language usage in diverse documents and media. - Develop semantic techniques for identifying the common topics, themes, and sentiment in speech and text in diverse foreign languages. - Explore techniques for optimizing combinations of existing resources to eliminate reliance on large parallel corpora in the context of exploiting foreign language sources in low-resource languages. ***FY 2016 Plans:*** - Develop algorithms to exploit the universal properties of languages when rapidly ramping up for a low-resource language. - 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.			
Title: Broad Operational Language Translation (BOLT) ***Description:*** The Broad Operational Language Translation (BOLT) program enabled language processing of informal and dialectal genres. Historically, foreign language translation technology was geared toward formal content, like broadcast media and newswire, but did not address informal or dialectal genres. BOLT developed new approaches to automated language translation, human-machine multimodal dialogue, and language generation and applied these to informal genres such as online discussion groups, messaging, and telephone conversation. While Chinese and dialectal Arabic were the two languages addressed directly in BOLT, techniques developed for these two languages have wide applicability to other languages and dialects. ***FY 2014 Accomplishments:*** - Developed improved algorithms for translating two informal genres of Arabic and Chinese text, online discussion groups and messaging, to enable comprehension of colloquialisms and idiomatic speech and added a third genre, telephone conversation. - Used methods developed for Egyptian dialectal Arabic to create databases, tools, and algorithms for additional Arabic dialects. - Developed dialogue management techniques such as computer-moderated turn-taking to avoid divergence as an approach for improving the performance of bi-directional Arabic-English dialogue systems. - Completed the annotated corpora of Arabic and Chinese informal genre data by adding new dialects and enhanced their utility by incorporating additional annotations.	38.913	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-04 / *LANGUAGE TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
- Formalized government purpose rights and transitioned software for translating informal genres of Arabic and Chinese to a Combatant Command and the Intelligence Community.			
Title: Multilingual Automatic Document Classification, Analysis and Translation (MADCAT) ***Description:*** The Multilingual Automatic Document Classification, Analysis and Translation (MADCAT) program developed and integrated technology to enable exploitation of foreign language hand-written documents. This technology is crucial to the warfighter, as documents such as notebooks, letters, ledgers, annotated maps, newspapers, newsletters, leaflets, pictures of graffiti, and document images captured in the field may contain extremely important time-sensitive information. The MADCAT program addressed this need by producing devices to convert such captured documents from Arabic into readable English in the field. MADCAT substantially improved applicable technologies, in particular document analysis and optical character recognition/ optical handwriting recognition. MADCAT integrated these improved technologies with translation technology and created prototypes for field trials. ***FY 2014 Accomplishments:*** - Fielded MADCAT to multiple Korean sites as an off-line capability for evaluation and routine use by end users. - Evaluated performance of MADCAT in the end user environment showing substantial progress in machine translation of Korean to English and English to Korean on end user provided documents in exercises conducted on site. - Distributed the MADCAT framework for access to the entire U.S. military on the Korean peninsula via the CENTRIX-K network and demonstrated the system during major annual combined U.S.-Korean Forces exercise Ulchi Freedom Guardian. - Developed and deployed a new machine translation capability enabling model adaptation using onsite data and continued to enhance end user learning and recall capabilities with translation memory capabilities. - Signed an MOU with the U.S. Army Chief of Staff in Korea which establishes responsibilities and commitments for MADCAT technology in Korea.	2.200	-	-
Accomplishments/Planned Programs Subtotals	74.332	45.511	60.897

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 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
IT-05: *CYBER TECHNOLOGY*	-	57.767	69.149	35.014	-	35.014	-	-	-	-	-	-

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 2014	FY 2015	FY 2016
Title: Plan X	35.599	43.419	25.150
Description: The Plan X program will develop 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 will create new graphical interfaces that enable intuitive visualization of events on hosts and networks to aid in the planning and execution of cyber warfare. Plan X will extend operationally meaningful measures to project quantitatively the collateral damage of executed cyber warfare missions. ***FY 2014 Accomplishments:*** - Created preliminary end-to-end system prototype that supports efficient network mapping, measurement, and network change detection applications. - Hosted private cloud infrastructure with automated provisioning of computing resources on a standalone closed network that enables a massively distributed data and event store. - Developed approaches to host Plan X control plane in a wide variety of network architectures using diverse scalable platforms. - Designed and implemented first generation prototypes of the commander, planner, and operator views for the graphical user interface. - Created automated network simulation technology to model the cyber battlespace, generate cyber warfare mission plans, and script cyber warfare missions using a domain specific language for programming at Internet scale. - Collaborated with operators from Air Force, Navy, Marine Corps, and Army cyber components and U.S. Cyber Command. ***FY 2015 Plans:*** - Create runtime environment and platforms capable of supporting a large scale user base, massive-scale deployments, resiliency to failures of any system component, and managing high ingest rates.			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Demonstrate cyber battle damage assessment from algorithmically placed vantage points. - Demonstrate military network tactical situational awareness applications and use cases. - Release Plan X 1.0 Alpha system and field test capabilities at military cyber exercises such as Cyber Flag and Red Flag. - Conduct field tests of computer network operations scenario development and training capabilities. - Create technical roadmap for transition to operational environment, including understanding of transition partner networks and integration points. ***FY 2016 Plans:*** - Release Plan X 1.0 Beta system and field test with military transition partners at cyber exercises such as Cyber Flag and Red Flag. - Publish application store software development kit and integrate third party cyber capabilities. - Demonstrate large-scale deployment of the end-to-end system with users and roles running on multiple devices in disparate locations. - 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. - Develop and implement technologies for multi-level security access and use privileges. - Integrate multi-level security access and use privileges and initiate technology transition with USCYBERCOM and Service components.			
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. Additional funding for this effort is provided in Project IT-03. ***FY 2014 Accomplishments:*** - Developed host phase of instrumented competition framework for automated cyber defense. - Initiated development of automated cyber defenders to identify flaws and formulate defenses. - Conducted competitive assessments to identify the most promising technology solutions. ***FY 2015 Plans:***	10.438	16.832	9.864

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014**	**FY 2015**	**FY 2016**
- Extend development of automated cyber defenders to allow real time in situ network defense decision making. - Develop a cyber research corpus using techniques from game theory, other quantitative disciplines, and emergent behavior. - Conduct mid-term qualification evaluation of cyber technologies through competitive challenges. ***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.			
Title: Crowd Sourced Formal Verification (CSFV) ***Description:*** The Crowd-Sourced Formal Verification (CSFV) program will create 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 will enable non-specialists to participate productively in the formal verification process by transforming formal verification problems into user-driven simulations that are intuitively understandable. ***FY 2014 Accomplishments:*** - Developed five web-based interactive computer simulations based on mapped high-level software specifications and codes. - Launched and maintained public web site to attract the widest possible base for crowd-sourcing formal verifications. - Applied simulations to large Java and C computer programs consisting of hundreds of thousands of lines of source code. - Mapped solutions as code annotations back into formal verification tools and assessed the effectiveness of these solutions by verifying the absence of errors on the MITRE Common Weakness Enumeration/SANS Institute Top 25 lists. - Refined initial simulations and began design and development of five new simulations for greater verification effectiveness. ***FY 2015 Plans:*** - Complete development of five new simulations. - Refine simulations to make them accessible to a large set of non-specialists. - Augment simulations to handle very large Java and C computer programs consisting of millions of lines of source code. - Enhance public web site to include these new simulations. - Assess effectiveness of the new simulations on the large-sized code targets.	11.730	8.898	-
Accomplishments/Planned Programs Subtotals	57.767	69.149	35.014

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-05 / *CYBER TECHNOLOGY*

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 2016 Defense Advanced Research Projects Agency	Date: February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602304E / *COGNITIVE COMPUTING SYSTEMS*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	15.847	-	-	-	-	-	-	-	-	-	-
COG-02: *COGNITIVE COMPUTING*	-	3.503	-	-	-	-	-	-	-	-	-	-
COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*	-	12.344	-	-	-	-	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Cognitive Computing Systems program element was budgeted in the Applied Research budget activity because it developed the next revolution in computing and information processing technology that enabled computational systems to have reasoning and learning capabilities and levels of autonomy far beyond those of today's systems. The ability to reason, learn and adapt raised computing to new levels of capability and powerful new applications.

The Cognitive Computing project developed core technologies that enabled computing and autonomy systems to learn and apply knowledge gained through experience. These technologies led to systems with increased self-reliance and the capacity to operate with reduced programmer and operator intervention. In resource-limited settings, these capabilities made the difference between mission success and mission degradation or failure, increased safety by allowing warfighters to operate systems from greater standoff distances, and reduced staffing requirements by providing greater autonomy.

The Collective Cognitive Systems and Interfaces project dramatically improved warfighter and commander effectiveness and productivity using advanced cognitive approaches that enabled faster, better informed, and more highly coordinated actions than those of our enemies. This was accomplished by developing revolutionary methods that increased our information processing capabilities, enhanced our situational awareness, and enabled more cohesive group action by our forces. Critical technical areas addressed in this project included automated decision support, information sharing, ensured communications, and advanced informatics.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602304E I *COGNITIVE COMPUTING SYSTEMS*

B. Program Change Summary ($ in Millions)	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	16.330	-	-	-	-
Current President's Budget	15.847	-	-	-	-
Total Adjustments	-0.483	-	-	-	-
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-0.483	-			

Change Summary Explanation

FY 2014: Decrease reflects the SBIR/STTR transfer.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602304E / *COGNITIVE COMPUTING SYSTEMS*	**Project (Number/Name)** COG-02 / *COGNITIVE COMPUTING*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
COG-02: *COGNITIVE COMPUTING*	-	3.503	-	-	-	-	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Cognitive Computing project developed core technologies that enabled computing and autonomy systems to learn and apply knowledge gained through experience. These technologies led to systems with increased self-reliance and the capacity to operate with reduced programmer and operator intervention. In resource-limited settings, these capabilities made the difference between mission success and mission degradation or failure, increased safety by allowing warfighters to operate systems from greater standoff distances, and reduced staffing requirements by providing greater autonomy.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Autonomous Robotic Manipulation (ARM) ***Description:*** The Autonomous Robotic Manipulation (ARM) program developed advanced robotic technologies that enabled autonomous (unmanned) mobile platforms to manipulate objects without human control or intervention. A key objective was intelligent control of manipulators to independently perform subtasks over a broad range of domains of interest to the warfighter, thereby reducing operator workload, time on target, training time, bandwidth, and hardware complexity. Former manipulation systems had many limitations. For example, while they performed well in certain mission environments, they had yet to demonstrate proficiency and flexibility across multiple mission environments; they required burdensome human interaction and the full attention of the operator; and the time required to complete tasks generally exceeded military users' desires. ARM created manipulators with a high degree of autonomy capable of serving multiple military purposes across a wide variety of application domains to include, but not limited to, counter-improvised explosive devices, countermine, search and rescue, weapons support, checkpoint and access control, explosive ordnance disposal, and combat casualty care (including battlefield extraction). ARM enabled autonomous manipulation systems to surpass the performance level of remote manipulation systems that are controlled directly by a human operator. ***FY 2014 Accomplishments:*** - Developed and demonstrated robust algorithms that locate and identify objects in various real-world scenarios. - Evaluated all performer autonomous algorithms through a series of experiments.	3.503	-	-
Accomplishments/Planned Programs Subtotals	3.503	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602304E / *COGNITIVE COMPUTING SYSTEMS*	**Project (Number/Name)** COG-02 / *COGNITIVE COMPUTING*

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 2016 Defense Advanced Research Projects Agency		Date: February 2015
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602304E / *COGNITIVE COMPUTING SYSTEMS*	**Project (Number/Name)** COG-03 / *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*	-	12.344	-	-	-	-	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Collective Cognitive Systems and Interfaces project dramatically improved warfighter and commander effectiveness and productivity using advanced cognitive approaches that enable faster, better informed, and more highly coordinated actions than those of our enemies. This was accomplished by developing revolutionary methods that increase our information processing capabilities, enhance our situational awareness, and enable more cohesive group action by our forces. Critical technical areas addressed in this project included automated decision support, information sharing, ensured communications, and advanced informatics.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Transformative Apps ***Description:*** Transformative Apps created the information infrastructure required to enable mission support and tactical applications (apps) to meet the efficiency, security, and availability requirements for use on mobile military networks. Particularly noteworthy was the development of a new data synchronization architecture between handheld devices and backend computing/storage nodes. Additionally, appropriate middleware services and libraries were developed to facilitate shared capabilities such as map viewing, apps management, and collection of logs, usage statistics, and user feedback. Apps, together with handhelds and networks, were tested in different training environments as well as in deployed environments. Performance and usage were carefully tracked and user feedback collected to guide rapid enhancement of apps. The effort created a military apps development community by reaching out to non-traditional performers and explored new models for software acquisition based on end-user empowerment. ***FY 2014 Accomplishments:*** - Demonstrated full interoperability across hybrid network topologies in a range of operationally relevant contexts. - Refined decentralized imagery processing and dissemination methods for below-brigade users. - Investigated enhanced counter-IED and situational awareness apps for training and CONUS exercises.	12.344	-	-
Accomplishments/Planned Programs Subtotals	12.344	-	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, **RDT&E Project Justification:** PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602304E / *COGNITIVE COMPUTING SYSTEMS*	**Project (Number/Name)** COG-03 / *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

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 2016 Defense Advanced Research Projects Agency	Date: February 2015
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*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	25.648	43.780	29.265	-	29.265	18.250	14.014	13.469	14.346	-	-
BW-01: *BIOLOGICAL WARFARE DEFENSE*	-	25.648	43.780	29.265	-	29.265	18.250	14.014	13.469	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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	24.537	44.825	52.560	-	52.560
Current President's Budget	25.648	43.780	29.265	-	29.265
Total Adjustments	1.111	-1.045	-23.295	-	-23.295
• Congressional General Reductions	-	-1.045			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	1.836	-			
• SBIR/STTR Transfer	-0.725	-			
• TotalOtherAdjustments	-	-	-23.295	-	-23.295

Change Summary Explanation

FY 2014: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2015: Decrease reflects congressional reduction for Section 8024, FFRDC.
FY 2016: Decrease reflects termination of chemical weapons defense program.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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 2014	FY 2015	FY 2016
Title: Medical Countermeasures	25.648	25.780	10.750

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 cost 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 2014 Accomplishments:
- Demonstrated that the modular platform can be used to predict the kinetics of metabolism and elimination that test compounds are known to exhibit in human physiological systems.
- Initiated design and construction of 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 two IVTCs individually responded and reacted to test compounds in a manner consistent with the known effects of those compounds on the corresponding human tissues.
- Demonstrated that a modular arrangement of the expanded set of two IVTCs can be used to predict the kinetics of metabolism and elimination that the test compounds are known to exhibit in human physiological systems.
- Investigated novel radiation dosimeter approach to mitigate exposure.

FY 2015 Plans:
- Demonstrate an expanded set of IVTCs able to reproduce the function of four human physiological systems.
- Demonstrate an automated prototype system for monitoring the health and response of IVTCs to test compounds.
- Design and build additional modules that are compatible with the expanded set of IVTCs and enable the platform to sustain the integrated IVTCs for two weeks.
- Demonstrate 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.
- Demonstrate 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.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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 2014	FY 2015	FY 2016
- 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.			
Title: Defense Against Mass Terror Threats ***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 Plans:*** - Develop the requirements for a low cost, pervasive detection network for wide area monitoring of radionuclide exposure. - Demonstrate 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.	-	18.000	18.515
Accomplishments/Planned Programs Subtotals	25.648	43.780	29.265

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	218.482	299.734	314.582	-	314.582	386.540	432.417	430.814	464.014	-	-
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	41.208	53.001	55.687	-	55.687	75.067	92.879	87.321	110.168	-	-
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	36.957	67.075	54.618	-	54.618	70.355	99.355	84.551	84.355	-	-
TT-06: *ADVANCED TACTICAL TECHNOLOGY*	-	19.582	19.494	15.968	-	15.968	33.200	35.672	39.467	24.443	-	-
TT-07: *AERONAUTICS TECHNOLOGY*	-	44.951	46.961	39.971	-	39.971	44.942	47.361	55.424	42.434	-	-
TT-13: *NETWORK CENTRIC ENABLING TECHNOLOGY*	-	75.784	113.203	148.338	-	148.338	162.976	157.150	164.051	202.614	-	-

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 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: a) compact, efficient, frequency-agile, diode-pumped, solid-state lasers for infrared countermeasures, laser radar, holographic laser sensors, communications, and high-power laser applications; and b) new tactical systems for enhanced air vehicle survivability, precision optics, electronic warfare, and advanced air breathing weapons.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*

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

The 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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	218.209	305.484	340.564	-	340.564
Current President's Budget	218.482	299.734	314.582	-	314.582
Total Adjustments	0.273	-5.750	-25.982	-	-25.982
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-10.000			
• Congressional Rescissions	-	-			
• Congressional Adds	-	4.250			
• Congressional Directed Transfers	-	-			
• Reprogrammings	6.724	-			
• SBIR/STTR Transfer	-6.451	-			
• TotalOtherAdjustments	-	-	-25.982	-	-25.982

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

	FY 2014	FY 2015
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 2014: Increase reflects reprogrammings offset by the SBIR/STTR transfer.

FY 2015: Decrease reflects congressional adjustments.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*

FY 2016: Decrease reflects completion of the Robotics Challenge program and the transition of the Endurance and Vertical Take-Off and Landing (VTOL) Technology Demonstration programs to Budget Activity 3.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	41.208	53.001	55.687	-	55.687	75.067	92.879	87.321	110.168	-	-

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 2014	FY 2015	FY 2016
Title: Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV)	22.951	19.000	8.000

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 2014 Accomplishments:
- Conducted ACTUV sensor and autonomy testing on surrogate platform.
- Initiated ACTUV prototype vessel construction.
- Signed Memorandum of Agreement with the Office of Naval Research for collaborative extended testing of the ACTUV platform.

FY 2015 Plans:
- Complete construction of prototype vessel.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Integrate software and hardware into the ACTUV platform. - Initiate at-sea testing to validate performance of vessel, sensor systems, and autonomy. ***FY 2016 Plans:*** - Continue at-sea testing of the completed ACTUV platform to demonstrate autonomy and baseline performance of ASW sensors. - Begin testing of improved ASW sensors. - 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.			
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 Project PE 0603766E/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 2014 Accomplishments:*** - Conducted system trade studies addressing a range of UFP applications leading to conceptual designs. - Conducted analysis to characterize long-range deep-sea communications. - Developed conceptual designs for deep-sea containment and launch. ***FY 2015 Plans:*** - Develop UFP nodes capable of extended survival at full depth. - Demonstrate the launch of a UFP surrogate payload to the surface from full depth. - Initiate development of payload subsystems for sensing, communications, and locating. - Demonstrate payload launch capabilities. - Initiate development of communications subsystems. - Study alternative communication modalities. ***FY 2016 Plans:*** - Complete development of payload subsystems for sensing, communications, and locating.	16.257	14.751	22.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Demonstrate deep-ocean launch of payload prototype to the surface with fully functioning subsystems. - Demonstrate the launch of a dormant UFP surrogate payload. - Complete development of communications subsystems. - Demonstrate long-range communications sufficient to wake up a UFP node. - Initiate integration of communications and UFP nodes.			
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. - Initiate development of select logistics technologies with high military payoff.	-	-	8.000
Title: Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES)* ***Description:*** *Previously Medium Caliber Precision Weapons, budgeted under Project TT-04. The Multi-Azimuth Defense Fast Intercept Round Engagement (MAD-FIRES) program will validate the premise that high precision extended range (1-10 km) direct fire medium caliber cannons can trade accuracy for size to provide equal or greater lethality compared to traditional larger and more expensive weapon systems. While MAD-FIRES does focus on the most stressing case; ship self defense against the newest and next generation maneuverable and high speed aerial threats, extending the technology could enable smaller combat fighting vehicles and platforms augmented survivability and lethality against larger, more valuable targets. Lethal direct fire overmatch traditionally required larger cannons and larger vehicles to overcome threat armor systems and defenses. MAD-FIRES will change this paradigm and enable smaller platforms by changing the requirement for maintaining lethality overmatch through accuracy rather than size. ***FY 2014 Accomplishments:***	2.000	12.000	17.687

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Conducted systems architecture trades and cost studies. - Initiated design studies of candidate weapons systems. ***FY 2015 Plans:*** - Initiate technology development efforts focusing on guidance, packaging and delivery method. - Conduct end-to-end modeling and simulation of all candidate designs. - Begin detailed subsystem design and plans for later stage risk reduction tests. - Begin examining candidate platforms for out-year live-fire tests. ***FY 2016 Plans:*** - Complete detailed subsystem design. - Complete all subsystem tests. - Coordinate with Navy for integrated tests to include approved representative targets.			
Title: Arctic Operations ***Description:*** The Arctic Operations initiative is focused on developing technology to assure U.S. capability to achieve situational awareness in the Arctic. Due to retreating Arctic ice in the coming decades there is an expectation for increased shipping traffic during the summer months, and increased interest in exploiting natural resources along the Arctic continental shelf. This growth in activity will increase the strategic significance of the region, and will drive the need to ensure stability through effective regional monitoring. The extreme environmental conditions of the Arctic may challenge the effectiveness of conventional technology to provide such monitoring. As such, this program seeks to exploit unique physical attributes and emergent environmental trends in the Arctic to create surprising new capabilities, and will develop technologies for persistent and affordable sensing and communication both above and below the ice to ensure responsive operations and domain awareness. ***FY 2015 Plans:*** - Initiate data collection analysis. - Complete data analysis from recovered data collection systems. - Complete data collection analysis from Navy Ice Experiment (ICEX).	-	3.000	-
Accomplishments/Planned Programs Subtotals	41.208	48.751	55.687

	FY 2014	FY 2015
Congressional Add: Arctic Operations Congressional Add ***FY 2015 Plans:*** - 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

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-03 / *NAVAL WARFARE TECHNOLOGY*

C. Other Program Funding Summary ($ in Millions)

Line Item	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
• ACTUV: *ONR PE 0603758N, Project 02918*	-	2.000	-	-	-	-	-	-	-	-	-
• ACTUV (line 2): *ONR PE 0602123N, Project 0000*	-	-	4.877	-	4.877	-	-	-	-	-	-
• ACTUV (line 3): *ONR PE 0603123N, Project 2912*	-	-	2.123	-	2.123	-	-	-	-	-	-

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 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	36.957	67.075	54.618	-	54.618	70.355	99.355	84.551	84.355	-	-

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 2014	FY 2015	FY 2016
Title: Ground Experimental Vehicle (GXV)	5.606	24.000	22.000

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, crew augmentation, and signature management, though other relevant technologies may also be pursued.

FY 2014 Accomplishments:
- Initiated research in GXV technology areas.

FY 2015 Plans:
- Continue GXV technology development efforts.
- Define initial concept vehicles based on emerging technologies.
- Develop parametric models for evaluating military utility of technologies.
- Conduct survivability analysis of individual vehicle concepts.

FY 2016 Plans:
- Continue research, development and integration of the most promising technologies.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Refine the concept vehicles based on the maturing technologies. - Develop modeling and situation tools to incorporate the advantages of the new technologies into existing campaign simulation tools.			
Title: Squad X ***Description:*** *Formerly Infantry Squad Systems (IS2) The U.S. military achieves overmatch against its adversaries via vehicles in all regimes - land, sea and air; 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 one-on-one overmatch as well as the overall integration of unmanned assets alongside the dismounts to create a new Hybrid Squad unit. ***FY 2014 Accomplishments:*** - Initiated CONOPS and systems architecture trade studies in the areas of soldier information interaction, network information management, and unmanned information interaction, engineering and perception as well as sensors, precision effects, and support technology for squad sensing, targeting and response. - Researched technology development efforts in the areas of situational awareness, command and control, and squad effects. ***FY 2015 Plans:*** - Initiate technology development efforts, focusing on enhanced sensor fusion and exploitation, squad collaborative autonomy, and squad organic precision effects. - Complete initial integration trade studies. - Complete technology evaluation and experimentation studies. - Develop virtual, constructive, and live experimentation plan; define modeling and simulation strategy. - Initiate development of virtual test bed. - Conduct Tactical Edge Standards Boards (TESBs) and service-level operational workshops. ***FY 2016 Plans:*** - Conduct virtual and live experiments to obtain a system performance baseline.	5.000	25.500	26.618

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014**	**FY 2015**	**FY 2016**
- Refine technology development efforts focusing on enhanced sensor fusion and exploitation, squad collaborative autonomy, and squad organic precision effects. - Implement modeling and simulation environment to allow for an overarching iterative design process and obtain system performance estimations. - Leverage Squad X testbed and simulation environments to iteratively assess developed technology and architecture schemes. - Initiate technology development interfaces focusing on human machine interfaces and the squad common operating picture. - Demonstrate initial individual technology capabilities in technology assessments.			
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 current or planned small off-road platforms (equivalent to high-mobility platforms currently used by special forces operators single rider, two-rider, or four-rider variants). The MI mixed teams will be able to execute an expanded mission set from those currently employed. The MI system concept will allow for a combined set of mounted and dismounted operations and for a larger area of operations over more aggressive timelines than standard infantry units. To improve operational effectiveness of the warfighter teams when dismounted, the semi-autonomous platforms, when unmanned, act as multipliers to the squad, such as extended and mobile fire support platforms and allow the MI mixed teams to perform higher risk exposure and access missions. The MI system scale, enabled by smaller off-road platforms, is intended to maintain dismounted warfighter scales for operational deployment. Platforms are planned for internal transportation within CH-47, CH-53, and V-22 aircraft and are intended to be adaptations of existing/expected platforms to eliminate the schedule and cost of new platform development. ***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. - Modify and demonstrate optionally manned configuration on an available all terrain vehicle.	-	-	6.000
Title: Robotics Challenge ***Description:*** The Robotics Challenge program will directly meet Department of Defense strategic needs by developing robotic technology for disaster response operations. This technology will improve the performance of robots that operate in the rough terrain and austere conditions characteristic of disasters, and use vehicles and tools commonly available in populated areas. This technology will work in ways easily understood by subject matter experts untrained in the operation of robots and be governed by	17.851	9.575	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
intuitive controls that require little training. The program will also meet the global need for resilience against natural disasters and industrial accidents, and increase the resilience of infrastructure against acts of terrorism. Anticipated Service users include the Army, Marines, and Special Forces. ***FY 2014 Accomplishments:*** - Built robot systems. - Developed algorithms for perception, manipulation, and operator interface. - Conducted the DARPA Robotics Challenge Trials. - Defined the DARPA Robotics Challenge Finals event performance and test criteria. ***FY 2015 Plans:*** - Conduct the DARPA Robotics Challenge Finals. - Perform analysis and report findings to document advancements achieved as a result of the challenge.			
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 by engaging a novel performer community in research efforts that result in prototype systems and proofs of concept in months, at a fraction of the cost of traditional design processes. The Robotics Fast Track program will engage numerous robotics related efforts across the spectrum of robotics professionals and enthusiasts, extending the existing performer base to include non-standard, cutting edge organizations and individuals throughout the robotics community. The program will demonstrate the ability for robotics projects to be performed at an asymmetric advantage in time, cost, and contribution of the efforts in comparison to more traditional applied research areas. This will apply to both performance of individual efforts and to the contracting required to engage performers in said efforts. ***FY 2014 Accomplishments:*** - Initiated outreach with nontraditional performer community. - Established baseline fundamental robotic system and subsystem needs. ***FY 2015 Plans:*** - Begin execution of multiple performance developments. - Release initial robotics fast track catalog.	1.500	8.000	-
Title: Fast, Adaptable, Next Generation Ground Combat Vehicle (FANG)	7.000	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
Description: The goals of the Fast, Adaptable, Next-Generation Ground Combat Vehicle (FANG) program were to employ a novel, model-based design and verification capability, a highly-adaptable foundry-style manufacturing capability, and collaborative design methods to demonstrate up to 5X compression in the timeline necessary to build an infantry fighting vehicle (IFV). The program sought to create an open-source development infrastructure for the aggregation of designer inputs applicable to complex electromechanical systems as well as software, and to exercise this infrastructure with a series of design events, leading to the building of designs in a foundry-style, rapidly configurable manufacturing facility. ***FY 2014 Accomplishments:*** - Conducted developmental testing and evaluation of the drivetrain and mobility subsystem built by the iFAB Foundry, including laboratory testing of a full up power pack (engine) and ground testing of a tracked vehicle. - Prepared notional design requirements for an IFV chassis and integrated survivability subsystem. - Conducted AVM tool suite validation testing, a rigorous test of META and iFAB capabilities executed by relevant industry teams and focused on the chassis and survivability subsystem of a heavy, amphibious IFV. - Transitioned component model standards, tool integration standards, and VehicleFORGE software tool suite and associated technology to the Digital Manufacturing and Design Innovation Institute (DMDII) through the use of co-funded research and formal technology transition activities for industry use. - Completed FANG Automotive Test Rig (ATR) build-out from the FANG Dynamometer Test Rig (DTR) Test Asset built by iFAB. - Executed Test Plan on FANG ATR Asset to compare real world performance with predicted performance in the AVM Tools. - Conducted focused iFAB manufacturing process capabilities assessment while transitioning AVM technologies to Army TARDEC and ARDEC (Benét Labs) through an End-to-End tool suite demonstration effort.			
Accomplishments/Planned Programs Subtotals	36.957	67.075	54.618

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 2016 Defense Advanced Research Projects Agency			**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
TT-06: *ADVANCED TACTICAL TECHNOLOGY*	-	19.582	19.494	15.968	-	15.968	33.200	35.672	39.467	24.443	-	-

A. Mission Description and Budget Item Justification

This project focuses on broad technology areas including: a) compact, efficient, frequency-agile, diode-pumped, solid-state lasers for infrared countermeasures, laser radar, holographic laser sensors, communications, and high-power laser applications; and b) new tactical systems for enhanced air vehicle survivability, precision optics, electronic warfare, and advanced air breathing weapons.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Endurance ***Description:*** The Endurance program will develop technology for pod-mounted lasers to protect a variety of airborne platforms from emerging and legacy electro-optical/infrared (EO/IR) guided surface-to-air missiles. The focus of the Endurance effort under TT-06 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 the phenomenology of laser-target interactions and associated threat vulnerabilities. The advanced technology component of this program is budgeted in PE 0603739E, Project MT-15. ***FY 2014 Accomplishments:*** - Developed preliminary designs for the objective brassboard system within the functional parameters of an objective flight-prototype. - Developed lethality data sets for representative legacy seekers. ***FY 2015 Plans:*** - Develop the critical design for the objective brassboard within the functional parameters of an objective flight prototype. - Develop 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:*** - Obtain all necessary approvals (range-safety, environmental, and laser-clearing house, etc.) for conducting live-fire testing. - Develop detailed system and sub-system requirements for a flight-prototype of a pod-mounted laser weapon system.	14.082	11.794	8.968
Title: LUSTER (Laser Ultraviolet Sources for Tactical Efficient Raman) ***Description:*** The Laser UV Sources for Tactical Efficient Raman (LUSTER) program is developing a compact semiconductor laser that emits in the deep UV (i.e. wavelength <250 nanometers) and is capable of an output power of 1 Watt with high efficiency	-	4.500	7.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
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 <250nm. 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 Plans:*** - Evaluate 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. - Evaluate development of laser pumping technologies, such as the use of compact electron-beam sources. - Evaluate methods for using non-linear crystals to efficiently convert longer wavelength lasers in the 500 nanometer range down to the 250 nanometer range. ***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 >100mW output power, 0.4% total system efficiency and line width less than 0.1nm.			
Title: International Space Station SPHERES Integrated Research Experiments (InSPIRE) ***Description:*** The International Space Station SPHERES Integrated Research Experiments (InSPIRE) program utilizes the DARPA-sponsored Synchronized Position, Hold, Engage, and Reorient Experimental Satellites (SPHERES) platform, which has 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 enhances the ability to rapidly mature and insert new technologies into national security space assets. The InSPIRE program expands on the capabilities matured through SPHERES by developing, building and launching new hardware and software elements that expand the baseline capabilities. These capabilities enable use of SPHERES as a testbed for more complex experimentation, providing affordable opportunities to test new space technologies. ***FY 2014 Accomplishments:*** - Built and ground tested docking ports for SPHERES to enhance rendezvous and docking test capabilities. - Built and ground tested new structures for SPHERES that expand upon its ability to integrate with additional hardware. - Conducted testing of tele-operations capabilities on the SPHERES devices on ISS, from the ground.	5.500	3.200	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Conducted testing of vision-based navigation hardware and software on the SPHERES devices on ISS. - Conducted testing of electromagnetic formation flight hardware and software on the SPHERES devices on ISS. - Developed and executed additional rendezvous and proximity operations experiments using SPHERES inside ISS. ***FY 2015 Plans:*** - Launch the new docking ports for SPHERES to enhance rendezvous and docking test capabilities. - Launch new structures for SPHERES that expand upon its ability to integrate with additional hardware. - Conduct on-orbit testing of new SPHERES docking ports and structures. - Develop and execute additional rendezvous and proximity operations experiments using SPHERES inside ISS.			
Accomplishments/Planned Programs Subtotals	19.582	19.494	15.968

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 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
TT-07: *AERONAUTICS TECHNOLOGY*	-	44.951	46.961	39.971	-	39.971	44.942	47.361	55.424	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 2014	FY 2015	FY 2016
Title: Aircrew Labor In-cockpit Automation System (ALIAS)	5.000	17.000	23.971

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 interfacing 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 2014 Accomplishments:
- Executed a ground-based proof of concept study refining an approach to crew station interfacing.
- Initiated development of core crew station technologies.
- Initiated development of adaptable learning approaches.

FY 2015 Plans:
- Design and commence prototyping of an initial ground-based ALIAS system.
- Initiate simulator-based demonstration of complete automation system including training and adaptation of system to multiple crew member roles.
- Conduct ground or airborne risk reduction testing and demonstrations.

FY 2016 Plans:
- Perform ground demonstration of ALIAS system functionality.
- Conduct flight demonstration of contingency management and new command interface.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Demonstrate portability to new aircraft type. - Continue risk reduction activities.			
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 2014 Accomplishments:*** - Performed testing of enabling technology components. - Initiated conceptual system designs. - Developed technology maturation plan and risk reduction strategy. ***FY 2015 Plans:*** - Initiate new studies of novel technologies. - Conduct risk reduction tests of candidate technologies. ***FY 2016 Plans:*** - Perform modeling of concepts and architectures. - Conduct trade studies of emerging concepts.	2.000	2.000	2.000
Title: Swarm Challenge ***Description:*** The goal of the Swarm Challenge is to develop autonomous swarming algorithms for Unmanned Vehicle (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 Plans:*** - Perform trade studies for system approach, functional and cognitive decomposition. - Select architecture for software, communication, computation, perception, and simulation environment.	-	3.000	6.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Develop autonomous algorithms and associated software. ***FY 2016 Plans:*** - Initiate first round of evaluation in simulated environment and then in physical environment. - Procure hardware and modify to enable demonstration of autonomy algorithms. - Improve cloud-based simulation environment and conduct virtual trials.			
Title: Gremlin ***Description:*** The goal of the Gremlin program is to develop platform technologies that enable a new class of distributed warfare. The Gremlin 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 Gremlin 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 Gremlin 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. - Study platform design trades and approaches to best meet performance goals at minimum cost.	-	-	8.000
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% of the ideal, and a lift-to-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. 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 2014 Accomplishments:*** - Performed trade studies to refine configuration and subsystem designs. - Defined software and hardware integration approaches and baseline controls necessary for successful air vehicle concept.	34.951	21.961	-

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Performed simulations to establish expected system level performance and validated the system concept and underlying enabling technologies. - Conducted 3D, unsteady Computational Fluid Dynamics (CFD) analyses for design refinements and convergence. - Utilized multi-point optimization techniques for design of subsystems and aerodynamics. - Performed multiple sub-system, wind tunnel and aerodynamic tests utilizing rapid prototyping for design verification and validation. - Evaluated performance capabilities, and conducted objective aircraft operational analyses. - Evaluated technical and programmatic risk elements, defined mitigation plans and analyses of alternatives. - Completed conceptual design of configurations and all subsystems. - Refined and consolidated flight test and validation approaches, flight test missions, and test range requirements. ***FY 2015 Plans:*** - Initiate preliminary design of configuration and all subsystems. - Hold system definition reviews to evaluate subsystem integration into air vehicle design and technology development paths to meet program objectives. - Perform subscale wind tunnel and laboratory testing for aerodynamic data base and flight controls development. - Refine power generation and distribution/integration concepts. - Perform propulsion and power system scaled model bench testing. - Design and develop subscale flight models for configuration viability and control law validation. - Conduct subscale model flight testing for controls development, verification, and validation. - Validate computational performance predictions against empirical data. - Refine full scale engine integration design. - Continue preliminary design refinements leading toward detailed design of the demonstrator aircraft and associated subsystems. - Create detailed system integration plans. - Prepare detailed airworthiness and flight test preparation requirements in support of flight test schedule.			
Title: Petrel ***Description:*** The Petrel program will investigate and develop advanced capabilities for the rapid transport of large quantities of cargo and equipment, such as in support of 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 7 days at a price point comparable or slightly in excess of conventional sealift. Petrel will fill the niche between conventional airlift and sealift through development of a new transportation mode capable of high speed operation across the surface/air interface over water as well as terrain. Technical approaches for rapid transport across the ocean and movement from the ship to the tactical battlefield will consider traditional and non-traditional aerodynamic and hydrodynamic concepts as well as innovative uses of	3.000	3.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
existing technologies. Primary technical goals for Petrel are to reduce or eliminate intermodal delays and to achieve a transport efficiency better than $0.1/ton-mi. ***FY 2014 Accomplishments:*** - Conducted studies to refine the operational trade space, defined limits of current technology, and informed new technical approaches. - Initiated concept designs focusing on transport efficiency, speed, and producibility. ***FY 2015 Plans:*** - Investigate component technologies with potential to enable specific concepts, including advanced propulsion and materials. - Explore innovative approaches for significantly increasing lift to drag ratio. - Evaluate approaches to rapidly deliver cargo and equipment directly from offshore to the battlefield without infrastructure. - Complete initial Petrel studies and conceptual system design work.			
Accomplishments/Planned Programs Subtotals	44.951	46.961	39.971

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 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
TT-13: *NETWORK CENTRIC ENABLING TECHNOLOGY*	-	75.784	113.203	148.338	-	148.338	162.976	157.150	164.051	202.614	-	-

A. Mission Description and Budget Item Justification

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. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: XDATA	25.800	33.217	38.717

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 2014 Accomplishments:
- Developed a framework for processing data from diverse sources with advanced analytics and visualization for diverse missions and platforms.
- Developed and demonstrated analytic tools for temporal and pattern analysis on data approaching petabyte scale.
- Initiated methods for uncertainty representation, processing, propagation, and visualization.
- Developed methods for dimensionality reduction for faster approximate processing with characterized accuracy.
- Developed adaptive visualization methods for large data for varying users and contexts.
- Developed an integrated framework for rapidly implementing analytics on a given computational platform with the ability to systematically trade off processing time and accuracy.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Demonstrated end-to-end systems in transactional problem domains from multiple defense mission areas. ***FY 2015 Plans:*** - Develop methods for interactive, iterative, and distributed analysis of diverse data at petabyte scale. - Optimize analytic methods and software for implementation on heterogeneous platforms and operating environments. - Optimize visualization technology to rapidly adapt to a new mission and context. - Demonstrate the initial implementation of a rich library of software tools for rapid use in mission and user specific contexts. - Demonstrate end-to-end systems on data and problems of end 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. - 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. - Explore additional infrastructure and computing architectures where disparate components reside in order to demonstrate the implementation of a rich, reusable library of software tools for rapid use in multiple missions and user specific contexts. - Develop a process for transition, exploring the benefits and limitations of embedded support to transition end-to-end systems, components, platforms and operating environments to identified end user communities.			
Title: Network Defense ***Description:*** The Network Defense program will develop 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 will develop 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 2014 Accomplishments:*** - Developed analytics that detect structured network attacks within a single network.	15.000	29.500	35.002

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Developed tailored algorithms to detect recurring threats on a single network. - Created a corpus of realistic benign and threat network data for test and evaluation of candidate techniques. ***FY 2015 Plans:*** - Enhance network analytics to detect structured attacks across multiple networks. - Create general purpose algorithms for detecting novel classes of attacks across multiple networks. - Develop methods for identifying persistent vulnerabilities within a network and across multiple networks. - Evaluate and optimize 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. - Demonstrate the capability to use summary information about an attack on one network to automatically detect similar attacks on other networks. - Transition capabilities to U.S. government and defense industrial base organizations/networks.			
Title: Memex ***Description:*** The Memex program will develop 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 will create 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 2014 Accomplishments:*** - Conceptualized and designed initial search architectures to support domain-specific search in high priority mission areas. ***FY 2015 Plans:*** - Develop domain-specific search engines to automatically discover, access, retrieve/extract, parse, process, analyze, and manage web content in specified domains.	3.000	23.758	29.300

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Implement the capability to index deep web and non-traditional structured and unstructured content that is dynamically-generated, unlinked, and in unconventional formats. - Develop information extraction techniques to categorize and classify discovered content based on mission/user task requirements. - Develop dynamic, interactive, and collaborative user interface capabilities to support the needs of specialized users. ***FY 2016 Plans:*** - Develop specialized search techniques for information discovery in social media. - 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.			
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 the contested environment. 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 2014 Accomplishments:*** - Developed architecture and concept of operations (CONOPS) for teams of manned and unmanned platforms coordinating to accomplish a mission in a denied environment. - Developed a simulation environment in parallel with technology development. - Developed detailed requirements and initiated system engineering for a mission-focused team-level distributed battle management system intended to operate in the denied environment.	5.000	12.024	17.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Explored and evaluated alternative architectures and cooperative control algorithms for team-level autonomy in a denied environment, as well as approaches for interacting with a human operator, and options for inserting software in operational platforms. ***FY 2015 Plans:*** - Develop detailed system architecture for the distributed battle management system. - Develop workflow and CONOPS for the human operator to interact with the battle management system. - Develop and prototype the protocols and algorithms for distributed battle management in a denied environment. - Stand-up modeling and simulation capability for test and performance evaluation and begin testing of prototype architecture and algorithms. ***FY 2016 Plans:*** - 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 DBM system architecture and software. - Demonstrate initial version's capabilities in a simulated battle environment with impaired communications and loss of critical resources. - Update DBM initial version to accommodate changes and new versions of software modules.			
Title: Quantitative Methods for Rapid Response (QMRR) ***Description:*** The Quantitative Methods for Rapid Response (QMRR) program develops and applies big data analysis and visualization methodologies for rapidly emergent U.S. national security priorities. As was shown by the Nexus 7 experience in Afghanistan, big data presents an opportunity to better understand the true nature of non-traditional threats, track the effectiveness of remedial measures, and develop/optimize alternative strategies; QMRR extends that work. Recently we have seen the rise of extremely challenging non-traditional threats such as ISIL and Ebola. In the case of ISIL, in addition to countering their military actions on the battlefield, it is important to limit the effectiveness of their recruitment efforts. Since ISIL recruiting is largely web-based, this implies the need to monitor ISIL public messaging in social media and private messaging on the dark web. Ebola presents related, but somewhat different challenges, specifically, finding patterns in the spread of the disease and factors that favor/mitigate its development. There is also interest in quantitative methods for countering proliferation of weapons of mass terrorism. The work conducted under the program will be coordinated with and transitioned to multiple national security agencies. ***FY 2015 Plans:*** - Develop quantitative models to track the development of ISIL force structure, funding, and logistics. - Develop quantitative models to track the spread of ISIL ideology with emphasis on the roles of social media and the dark web. - Develop quantitative models to track the spread of Ebola with emphasis on social and economic factors.	-	8.600	15.588

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Develop quantitative models to track the proliferation of weapons of mass terrorism. - Coordinate with stakeholders in national security agencies and develop mechanisms for transitioning technology to operations. ***FY 2016 Plans:*** - Refine quantitative models to track the development of ISIL force structure, funding, and logistics. - Refine quantitative models to track the spread of ISIL ideology with emphasis on the roles of social media and the dark web. - Refine quantitative models to track the spread of Ebola with emphasis on social and economic factors. - Refine quantitative models to track the proliferation of weapons of mass terrorism. - Transition technology to operations.			
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. In the future, the U.S. military will encounter adversary systems that are AI-enabled. Maintaining "AI-superiority" will require AI-enabled systems capable of performing increasingly complex functions with high degrees of reliability and safety. Significantly, in order for developers and users to feel confident enough to deploy and use AI-enabled systems, these systems must operate with a high degree of transparency. UMI will develop AI technologies that support transparency by providing supporting rationale and logic sequences to clarify 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 and interrupt anomalous outputs and behaviors. UMI implementations will be developed and demonstrated in next-generation systems. ***FY 2016 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 systems analogous to the (conventional) stability theory developed for dynamical systems.	-	-	12.731
Title: Visual Media Reasoning (VMR) ***Description:*** The Visual Media Reasoning (VMR) program is creating technologies to automate the analysis of enemy-recorded photos and videos and identify, within minutes, key information related to the content. This includes the identification of individuals within the image (who), the enumeration of the objects within the image and their attributes (what), and 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 will enable users to gain insights rapidly through application of highly parallelized image analysis techniques that can process	15.000	6.104	-

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
the imagery in massive distributed image stores. VMR technology will serve 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 2014 Accomplishments:*** - Optimized the core reasoning engine to make reliable inferences across the Who, What, Where and When domains to produce more accurate answers to warfighter and intelligence analyst queries. - Extended indexing to video clips. - Enhanced detection of the geo-physical content of images: water, desert, urban, interior, etc. - Implemented image/video frame triage so reasoning is applied to scene-like images only. - Delivered an experimental prototype for evaluation by the National Media Exploitation Center (NMEC) as a potential transition partner, and received inquiries from over 20 different federal groups interested in the technology. ***FY 2015 Plans:*** - Configure the reasoning engine so the user can customize selected reasoning assumptions, such as typical vehicle size, to enhance query results for specific applications. - Include mechanisms for technical users to add new computer vision algorithms to the system. - Provide a quantified level of performance to show the advantage of multi-algorithm reasoning versus a single-algorithm approach. - Deliver robust full-featured prototypes to NMEC and the FBI as transition products.			
Title: Nexus 7 ***Description:*** The Nexus 7 program applied forecasting, data extraction, and analysis methodologies to develop tools, techniques, and frameworks for the automated interpretation, quantitative analysis, and visualization of social networks. Social network theory has emerged in recent years as a promising approach for understanding groups of individuals connected through a variety of shared interests and collaborative activities. For the military, social networks provide a promising model for understanding terrorist cells, insurgent groups, and other stateless actors whose connectedness is established not on the basis of shared geography but rather through the correlation of their participation in coordinated activities such as planning meetings, training/ mission rehearsal sessions, sharing of materiel/funds transfers, etc. Nexus 7 supported emerging military missions using both traditional and non-traditional data sources for those areas of the world and mission sets with limited conventional Intelligence, Surveillance and Reconnaissance. Examples of additional data sources included foreign news, media, and social network data. These non-traditional sources were integrated with a wide variety of military structured and unstructured data. Nexus 7 developed quantitative techniques and tools for processing and analyzing these large data sources as a means for understanding relationships between hostile, neutral, and friendly foreign organizations with the United States. ***FY 2014 Accomplishments:***	11.984	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Developed quantitative techniques and tools for processing, analyzing, and visualizing increasingly large volumes of cyber-social data. - Created and deployed analytics for emerging DoD mission areas to Combatant Commands and other U.S. Government agencies. - Completed drawdown of forward deployed analytical cell in Afghanistan. - Transitioned suite of algorithms, software, and tools throughout DoD including DCGS-Army.			
Accomplishments/Planned Programs Subtotals	75.784	113.203	148.338

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	158.948	150.389	220.115	-	220.115	263.319	255.711	286.955	288.338	-	-
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	121.280	101.213	130.140	-	130.140	138.903	120.669	130.560	125.928	-	-
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	37.668	49.176	89.975	-	89.975	124.416	135.042	156.395	162.410	-	-

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 2016 Defense Advanced Research Projects Agency	Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	166.654	160.389	200.725	-	200.725
Current President's Budget	158.948	150.389	220.115	-	220.115
Total Adjustments	-7.706	-10.000	19.390	-	19.390
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-10.000			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-2.779	-			
• SBIR/STTR Transfer	-4.927	-			
• TotalOtherAdjustments	-	-	19.390	-	19.390

Change Summary Explanation

FY 2014: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2015: Decrease reflects congressional reduction.

FY 2016: Increase reflects expanded efforts in therapeutic interventions to modulate immune response, and increased focus on improving integration of biological processes and computing systems to optimize human-computer effectiveness.

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

Appropriation/Budget Activity	R-1 Program Element (Number/Name)	Project (Number/Name)
0400 / 2	PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	121.280	101.213	130.140	-	130.140	138.903	120.669	130.560	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 2014	FY 2015	FY 2016
Title: Materials Processing and Manufacturing	23.753	20.716	27.049

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 2014 Accomplishments:
- Validated predictive capability of process models on material properties and microstructure as well as component performance, quality level, and manufacturing effectiveness.
- Developed new probabilistic models and reliability quantification methodologies for rapid qualification.
- Developed and demonstrated manufacturing assessment tools for select new manufacturing technologies.
- Established cost models for additive manufacture of selected components that provide a reduction in cost and time over standard fabrication baselines.
- Established a library of process models and manufacturing data to support model use and improvement.

FY 2015 Plans:
- Demonstrate 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).

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Implement in-process quality assurance (IPQA) sensors and technology capable of capturing DMLS processing data, and initiate development of optimized capture of real time data at appropriate resolutions to forecast article quality. - Demonstrate 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. - Demonstrate automated X-Y-Z wire position control system based on real-time, fast rate, solid-state backscattered electron sensor system. - Simulate high fidelity probabilistic process window (including tails) for bonded composite structures using Monte Carlo techniques and a priori knowledge of process variables. - Complete verified 2D and 3D bonded composite pi-joint structure models. - Establish interoperable process-material model assessment framework, and curate and standardize a data management system to capture and store data from materials and manufacturing research. - Formulate approaches for accepting natural inputs for mechanical and software design. ***FY 2016 Plans:*** - Complete design of experiments (DOE)-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. - Formulate approaches for accepting natural inputs for mechanical and software design. - Develop techniques for identifying underspecified elements in mechanical and software designs. - Develop interactive dialog techniques for obtaining design information from a human user.			
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,	22.665	18.734	22.900

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
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 2014 Accomplishments:*** - Integrated flux, mobility and reactivity process components to validate low-temperature deposition of DoD-relevant thin film coatings that currently require high bulk temperature. - Quantified temporal and spatial stability of reactive species at ambient temperature for a DoD-relevant thin film coating in an integrated deposition system. - Initiated comprehensive local control approach to thin film synthesis. - Integrated fiber-reinforced reactive matrix and high-stiffness amorphous metals into reactive case structures and characterized dynamic mechanical response. - Demonstrated ability to survive penetration into reinforced concrete with a minimal amount of strain deformation. - Demonstrated survivability of impact into reinforced concrete at ballistic velocities. - Demonstrated scalability to low-rate manufacturing scales while maintaining blast enhancement of survivable materials over inert cased charge. ***FY 2015 Plans:*** - Experimentally validate computational models of low temperature thin film growth. - Integrate in situ thin film characterization techniques for real-time qualitative and quantitative analysis of growth processes. - Demonstrate deposition of thin film challenge material on a substrate at low temperature. - Improve film quality and properties by adjusting process component parameters/integration strategy. - Generate design intent and the initial materials solution for a baseline hypersonic flight trajectory. - Establish and populate the data warehouse for initial boost-glide aeroshell data. - Develop an initial mathematical modeling framework for modeling complex systems applicable to many domains. ***FY 2016 Plans:*** - Deliver thin film coating materials, and technical summaries to transition partners, Army Research Office and the Naval Air Systems Command. - 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.			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- 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. - Explore analytical techniques for characterizing complex system phase transitions and regimes of emergent behavior across scales of time and space. - Design an open source, agent based hardware/software platform for evaluating algorithms for modeling complex systems across multiple scales. - Explore coupling of agent based modeling with amorphous computing methods and new meso and macro-scale representations of complex, dynamic systems for design and modulation of local interactions for desired global properties.			
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 in this thrust are energy management and armor approaches to address explosively formed projectiles (EFP) 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 2014 Accomplishments:*** - Integrated material properties and energy management mechanisms into ballistic armor materials optimized for single threat defeat in each regime (bullet, frag, EFP) to meet survivability objectives. - Demonstrated at least 30% enhancement in opaque vehicle ballistic armor performance in each regime (bullet, frag,) for single threats over state-of-the-art fielded designs. - Conducted a study, based on single threat results, to establish feasibility of achieving 2x enhancement in opaque vehicle ballistic armor performance for multiple threats. - Continued to identify and evaluate promising new armor concepts from non-traditional organizations both for military personnel and vehicles. - Demonstrated >2x enhancement in energy absorption capability of candidate materials over currently employed materials. - Determined feasibility to reduce effects of localized dynamic loading in an underbody blast event by 50% over state-of-the-art. - Determined feasibility to reduce effects of global impulse in an underbody blast event by 50% over state-of-the-art. ***FY 2015 Plans:*** - Demonstrate at least 30% enhancement in opaque vehicle ballistic armor performance for combined bullet-frag threats over state-of-the-art fielded designs. - Demonstrate 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.	26.159	18.749	19.633

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Develop 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. - Incorporate the best promising new armor concepts from non-traditional organizations into integrated ballistic armor design and demonstrate performance. - Develop and demonstrate 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. - Integrate energy absorbing materials and components into passive hierarchical energy absorbing systems characteristic of various vehicle weight classes and demonstrate capability to reduce by >2x the combined effects of local and global impulse in underbody blast events. - Demonstrate capability to reduce by >2x the combined effects of local and global impulse in active counter impulse systems characteristic of various vehicle weight classes in underbody blast events. - Demonstrate capability to reduce by >4x the effects of both local and global impulse by combining hierarchical passive energy absorbing and active counter impulse systems into integrated systems characteristic of various vehicle weight classes in underbody blast events. - Explore novel approaches to chemical remediation of organic compounds with a focus on approaches that utilize readily available reagents (e.g., soil, water and air). - Develop modeling capability for predicting material properties relationships such as density, strength, and toughness in hierarchical structures. ***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%. - Explore the feasibility of exploiting rational, hierarchical design approaches to enable adaptive smart structures that can sense and actuate in response to environmental challenges. - Couple computational physics/mechanical tools with emerging material design concepts to achieve combinations of structural and functional properties that do not coexist in conventional materials. - Initiate the development of functional materials and structures with properties that are invariant across varying operational environments (for example, pressure and temperature).			
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 area of focus under this thrust is the development of wearable (i.e., ultra-low size, weight and power) optical systems to enhance warfighter situational awareness. Another focus area is the development of improved transductional materials that convert one	9.668	6.000	12.500

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
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 SWaP thermoelectric coolers for DoD infrared sensors and compact RF antennas. ***FY 2014 Accomplishments:*** - Demonstrated and conducted user testing of hands-free zoom capability. - Assembled and tested wide field of view compact camera. - Demonstrated integrated software environment for image collection and processing. ***FY 2015 Plans:*** - Explore and develop an open source model architecture and platform applicable to multiple transductional material domains (e.g. thermoelectric, magnetoelectric, multiferroic). - Identify canonical DoD relevant system specification that will provide performance requirements for transductional material development efforts. ***FY 2016 Plans:*** - Develop multi-physics transductional material modeling capability that incorporates aperiodic interface modeling and phonon engineering. - Improve multi-physics transductional material modeling capability to include surface and quantum confined structures. - Integrate new multi-physics models with experimental data from transductional materials development efforts.			
Title: Manufacturable Gradient Index Optics (M-GRIN) ***Description:*** The Manufacturable Gradient Index Optics (M-GRIN) program seeks to advance the development of GRIN lenses from a Technology Readiness Level (TRL) 3 to a Manufacturing Readiness Level (MRL) 6. The program will expand the application of gradient index optics (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 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	11.800	7.814	7.500

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
unattainable 3D 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 2014 Accomplishments:*** - Demonstrated GRIN lens-based systems with at least 2x weight reduction from homogenous system with equivalent performance. - Advanced MRL and commenced process characterization and control to improve yields and rapid redevelopment cycles. - Commenced demonstration of rapid redevelopment/prototype manufacturing capability by producing multiple GRIN lenses from the same manufacturing process. - Completed prototype designs to demonstrate breadth of improved DoD-relevant parameters/properties (wide field-of-view, f-number, bandwidth, etc.) in manufactured optical components. - Established physical models for diffusion and molding to inform manufacturing processes. - Expanded IR metrology for program materials. - Characterized thermal properties of M-GRIN materials and began thermal modeling for optical properties. - Commenced expansion of design tools to add 3D and arbitrary gradients as well as improve computational efficiency. ***FY 2015 Plans:*** - Complete GRIN lens production scale-up and demonstrate process control as measured against target yield and cost, to enable sustainable manufacturing. - Upgrade design tools and expand 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. - Complete expansion of design tools to add 3D and arbitrary gradients as well as improve computational efficiency. - Complete process characterization and control to achieve target yields and turn-around times. - Initiate prototype builds to demonstrate system performance and/or size, weight and power (SWaP) improvement from GRIN optical systems. - Initiate thermal model and implement in optical system design to mitigate thermal effect on optical performance. - Initiate 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. - Achieve MRL 6 and demonstrate stable GRIN manufacturing capability. - Demonstrate intermediate volume capability through repeatable production of several small lots.			
Title: Reconfigurable Structures	14.735	14.200	18.058

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
Description: In the Reconfigurable Structures thrust, new combinations of advanced materials, devices, and structural architectures are being developed to allow military platforms to move, morph, or change shape for optimal adaptation 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. ***FY 2014 Accomplishments:*** - Completed design of actuation system for a humanoid robot, including bench-top testing of high-risk components and/or subsystems. - Designed actuation systems for a humanoid robot that increases its energy efficiency by 20x, using the same kinematic structure, energy source, computing, and low-level control software. - Demonstrated advanced energy-efficiency improvement actuation approaches by quantitative analysis and/or simulation. - Initiated experiments to validate advanced energy-efficiency improvement actuation approaches. ***FY 2015 Plans:*** - Explore materials systems with capacity to create self-assembled obstacles to structures. - Investigate self-assembled structures that can self-adhere to surfaces. - Investigate new control algorithms and sensing modalities to enable sensing and processing for fast autonomous maneuvers in cluttered environments. - Design platforms to be used as Government-Furnished Equipment (GFE) for low-Size, Weight and Power (SWaP) experimentation involving fast autonomous maneuvers. ***FY 2016 Plans:*** - Identify designs for self-assembling obstacle system architectures with compact dimensions. - Demonstrate feasibility for self-assembling obstacles that can resist assault. - Determine limits for GPS free navigation for short duration missions. - Model and develop sensor, processor, and behavioral controls to enable an ISR mission in a moderate-clutter environment.			
Title: Advanced Technology Heat to Electricity Nuclear Alternatives (ATHENA) ***Description:*** The Advanced Technology Heat to Electricity Nuclear Alternatives (ATHENA) program is an experimental program to determine if it is possible to provide electrical power for military missions with very high energy density and power density, at a scale where nuclear reactors are unworkable, where combustion is infeasible, and where solar power is impractical,	-	5.500	7.500

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
for space, maritime, and ground applications. The program pursues advancements in radioisotope technology, which has essentially stagnated for fifty years. Specifically, the program seeks to identify and develop radioisotopes that better capture DoD requirements by providing improved power density and allow safer, more convenient handling, explore better and more efficient electricity conversion technology than thermocouples, and to develop an operations framework leading to a solution that is capable of deployment. ***FY 2015 Plans:*** - Initiate isotope evaluation and selection. - Develop competing technologies for electricity conversion at small (battery) scale and large (~10 kW) scale. - Conduct assessment of costs of production, deployment, and handling of selected radioisotope material. ***FY 2016 Plans:*** - Demonstrate prototype conversion technology for radioisotope energy at power density better than solar arrays. - Demonstrate production and handling of candidate radioisotopes for power use. - Conduct testing of battery scale and heat engine scale conversion devices to determine real-world efficiency.			
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 Plans:*** - Develop and refine notional high-voltage particle accelerator system architectures for neutron production. - Design components with 10-100x performance in key metrics as determined by system architecture requirements. - Develop and use 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 accelerator. - Refine components and begin integration into demonstration neutron source testbed.	-	9.500	15.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
- Use component performance tests for design tool validation and development.			
Title: Structural Materials and Coatings ***Description:*** The Structural Materials and Coatings thrust explored and developed new materials to provide enhanced structural and/or surface properties for DoD applications. Included were approaches that avoid corrosion through engineered material, provide superior strength at greatly reduced material density, provide the basis for a new generation of structural composite and submarine propeller materials, and enable prolonged lifetimes for DoD systems and components. The Hybrid Multi Material Rotor Full-Scale Demonstration (HyDem) program, an outgrowth of the Structural Materials and Coatings effort's Hybrid Multi Material Rotor (HMMR) program, dramatically improved U.S. Navy submarine superiority. The HyDem program designed, manufactured, and supplied the Navy with a novel component for integration into a new construction Virginia Class Submarine. The Navy is evaluating this component in sea trials. If successful, it is envisioned that the Navy will integrate this design change into the future development of the Virginia Class and Ohio Replacement Submarines, and possibly back-fit previously constructed Virginia Class Submarines. Beginning in FY 15 this program will be funded from PE 0603766E, Project NET-02, Maritime Systems. ***FY 2014 Accomplishments:*** - Completed concept design, demonstrating the ability to scale from 1/4-scale HMMR to full-scale component. - Completed preliminary design, demonstrating that the design accommodates stated performance parameters. - Performed analysis of shock test of scaled components. - Developed manufacturing process plans for full-scale components. - Delivered large-scale rotor component to the Navy for in-water testing and assessment. - Initiated fabrication of large-scale rotor for Navy assessment.	12.500	-	-
Accomplishments/Planned Programs Subtotals	121.280	101.213	130.140

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 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	37.668	49.176	89.975	-	89.975	124.416	135.042	156.395	162.410	-	-

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 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: BioDesign	11.438	11.500	17.500

Description: BioDesign will employ system engineering methods in combination with biotechnology and synthetic chemical technology to create novel beneficial attributes. This thrust area includes designed molecular responses that increase resistance to cellular death signals and improved computational methods for prediction of function based solely on sequence and structure of proteins produced by synthetic biological systems. Development of technologies to genetically tag and/or lock synthesized molecules would provide methods for prevention of manipulation ("tamper proof" synthetic biological systems). This thrust will also 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.

FY 2014 Accomplishments:
- Developed genomic security technologies in research microbes and preparing to test functionality in commercially relevant microbes.
- Evaluated high-throughput methods that have the potential to map intracellular proteins.
- Developed a path to detect intracellular components and events that are present in quantities ranging from fifty to thirty million copies per cell.
- Developed a plan to detect intracellular molecules with masses ranging from fifty to two hundred thousand Daltons.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Initiated development of high throughput analytical equipment to measure the concentration of >1000 proteins simultaneously. ***FY 2015 Plans:*** - Utilize high throughput approaches to characterize intracellular components and mechanistic interactions that reveal the effects of challenge compounds on intracellular machinery. - Demonstrate high throughput methods using cells of human origin. - Demonstrate the ability to identify intracellular components and events that occur hours after the application of a challenge compound. - Demonstrate the ability to localize relevant molecules and events to one intracellular compartment (membrane, nucleus, or cytoplasm) upon the application of a challenge compound. - Reconstruct and confirm 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. - Research platform technologies to characterize molecular responses between members of a complex microbial community. ***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. - Research advanced bio-based platforms for early detection and mitigation of threats, such as infectious diseases, novel functions, and defense applications.			
Title: Living Foundries ***Description:*** The goal of the Living Foundries program is to create a revolutionary, biologically-based manufacturing platform to provide new materials, capabilities, and manufacturing paradigms 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. However, the DoD's ability to harness this platform is rudimentary. 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. The program will enable the rapid and scalable development of previously unattainable technologies and products (i.e., those that cannot be accessed using known, synthetic mechanisms), leveraging biology to solve challenges associated with production of new materials (e.g., fluoropolymers, enzymes, lubricants, coatings and materials for harsh environments), novel functions (e.g., self-repairing and self-regenerating systems), biological reporting systems, and therapeutics to enable new solutions and	18.155	23.122	30.900

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016

enhancements to military needs and capabilities. Ultimately, Living Foundries aims to provide game-changing manufacturing paradigms for the DoD, enabling distributed, adaptable, on-demand production of critical and high-value materials, devices, and capabilities in the field or on base. Such a capability will decrease the DoD's dependence on tenuous material supply chains vulnerable to political change, targeted attack, or environmental accident.

Research thrusts will focus on the development and demonstration of open technology platforms, or bioproduction pipelines, that integrate the tools and capabilities developed in PE 0601101E, TRS-01 to prove out capabilities for rapid (months vs. years) design and construction of new bio-production systems for novel materials. 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. Integrated processes developed in this program will translate into significant performance improvements and cost savings for the production of advanced materials, biological reporting systems, and therapeutics. These technologies will ultimately result in on-demand, customizable, and distributed production of strategic materials and systems. 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 and chemical building blocks with complex functionalities, such as synthesis of advanced, functional chemicals, materials precursors, and polymers (e.g., those tolerant of harsh environments).

FY 2014 Accomplishments:
- Continued standardization, integration, and automation of the fundamental tools and capabilities developed in PE 0601101E, TRS-01 into a readily adoptable and adaptable biomanufacturing platform.
- Began to integrate data streams (using previously developed computation algorithms and software) from fabrication, quality control and characterization tools to provide a comprehensive debugging capability and to enable forward design.
- Began to demonstrate, test, and evaluate the extent of design-build-test cycle compression using integrated platforms to engineer new bioproduction systems.
- Initiated development of rapid design and prototyping infrastructure pipelines, including initial system integration and process optimization.
- Began testing the ability of integrated infrastructure pipelines to demonstrate rapid, improved prototyping of DoD-relevant molecules.

FY 2015 Plans:
- Demonstrate the ability of each infrastructure pipeline to rapidly generate DoD-relevant molecules.
- Expand the capabilities of the rapid design and prototyping infrastructure to target molecules and chemical building blocks that are currently inaccessible using traditional synthesis mechanisms.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Complete proof-of-concept demonstrations of component technologies developed under PE 0601101E, TRS-01 that accelerate the design-build-test cycle. - Expand access and experimental scale to promote the production capabilities of rapid design and prototyping facilities infrastructure. - Begin establishing the efficacy of the integrated design-build-test-learn feedback cycle for forward design and rapid optimization of novel, currently inaccessible molecules via the prototyping facility's established processes. ***FY 2016 Plans:*** - Continue demonstrating infrastructure pipelines capable of rapidly prototyping and generating DoD-relevant molecules. - Demonstrate the rapid design and prototyping of currently inaccessible (not synthesizable by traditional biologic or synthetic chemistry processes) target molecules and materials by the established prototyping facilities. - Continue integrating demonstrated component technologies developed under PE 0601101E, TRS-01 to further enhance the capabilities of the rapid design and prototyping pipelines. - 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.			
Title: Adaptive Immunomodulation-Based Therapeutics ***Description:*** The Adaptive Immunomodulation-Based Therapeutics program will develop platform technologies that can interrogate and define the biological pathways leading to an immune response with the goal of developing and demonstrating new therapeutic interventions. One approach to achieve this capability will require the development of new tools to stimulate and measure responses of the nervous system in order to map the bioelectric code that controls the immune response as well as other critical organ functions. This program will also develop capabilities for serial measurements of metabolic state to identify correlates for health and early detection of disease. An additional approach involves characterizing the host response in patients with severe infections, and translating this response into 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 and could later be expanded to track the health of various communities. 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 with no available drugs, such as multiple drug resistant organisms. The ultimate goals for the Adaptive Immunomodulation-Based Therapeutics program are to enable an autonomous and continuous sense and response capability to regulate the human immune response and to develop decision support tools that help manage general health such as tracking and combatting infectious diseases in a community. It is anticipated that these capabilities will ultimately provide	-	12.554	23.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
enhanced protection against injury, enable life-saving rescue from hyper-immune activity, and stimulate advances in regenerative medicine. ***FY 2015 Plans:*** - Develop capabilities to characterize the neural-immune interface, including real-time measurement of biomarkers. - Identify novel, actionable targets for neural immune modulation. - Identify 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. - Demonstrate superior specificity of novel interface technologies compared to FDA-approved 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. - Initiate testing of advanced interface technologies.			
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 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. - Explore mechanisms for direct neural interfacing to receive and react to operationally relevant environmental, physiological and neural information. - Begin researching scalable models and algorithms to derive actionable biological signals from multiple users.	-	-	10.500

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Begin studying approaches to transform neural representations of meaning, content and intentionality to new communications protocols.			
Title: Biological Robustness in Complex Settings (BRICS) ***Description:*** The Biological Robustness in Complex Settings (BRICS) Program will leverage newly developed technologies for engineering biology towards enabling radical new approaches to solving National Security challenges. 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). - Develop analytical tools that allow the simultaneous measurement of relevant parameters, such as gene transcription, protein synthesis, 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. - Integrate promising component technologies that may be readily adapted into a platform for engineering robust, stable, and safe biological communities.	-	-	8.075
Title: Neuroscience Technologies ***Description:*** The Neuroscience Technologies thrust leverages 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 will create modern neuroscientific techniques to develop quantitative models of this impact and explore mechanisms to protect, maintain, complement, or restore physical and cognitive functioning during and after exposure to operational stressors. In addition, new approaches for using physiological and neural signals to make human-machine systems more time efficient and less workload intense will be identified, developed, and evaluated. This thrust area will have far-reaching implications for both current and future	8.075	2.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
military operations, with the potential to protect and improve physical and cognitive performance at the individual and group level both prior to and during deployment. ***FY 2014 Accomplishments:*** - Determined genetic, epigenetic, and proteomic changes underlying vulnerability to poor decision making in humans. - Developed tools and metrics for evaluating individual and group performance during close-quarters combat training and other operationally relevant training scenarios. - Exploited advances in predictive models of the brain and investigated new modeling methods to develop tools and techniques that can characterize and improve cognitive performance under stress at the individual level. ***FY 2015 Plans:*** - Investigate 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. - Exploit 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. - Research methods for joint computation and operations between biological systems and traditional digital computing systems.			
Accomplishments/Planned Programs Subtotals	37.668	49.176	89.975

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	222.287	169.203	174.798	-	174.798	170.783	198.083	195.175	198.347	-	-
ELT-01: *ELECTRONICS TECHNOLOGY*	-	222.287	169.203	174.798	-	174.798	170.783	198.083	195.175	198.347	-	-

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. Another thrust of the program element will explore alternatives to silicon-based electronics in the areas of new electronic devices, new architectures to use them, 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.

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B. Program Change Summary ($ in Millions)

	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	233.469	179.203	183.439	-	183.439
Current President's Budget	222.287	169.203	174.798	-	174.798
Total Adjustments	-11.182	-10.000	-8.641	-	-8.641
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-10.000			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-4.280	-			
• SBIR/STTR Transfer	-6.902	-			
• TotalOtherAdjustments	-	-	-8.641	-	-8.641

Change Summary Explanation

FY 2014: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2015: Decrease reflects congressional reduction.
FY 2016: Decrease reflects completion of several electronics technology programs such as: Nitride Electronic NeXt-Generation Technology, Microscale Plasma Devices, and Micro-coolers for Focal Plane Arrays.

C. Accomplishments/Planned Programs ($ in Millions)

	FY 2014	FY 2015	FY 2016
Title: Adaptive Radio Frequency Technology (ART)	29.009	24.003	15.550

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
FY 2014 Accomplishments: - Demonstrated reconfigurable RF circuit (RF-FPGA) technologies at the component and system levels along with the necessary computer-aided design approaches. - Demonstrated 100x improvement in the number of times high performance phase-change switches can be switched on and off. - Developed and demonstrated new integration process for phase-change switches that will enable demonstration at multi-system reconfiguration level. - Manufactured a second-generation single reconfigurable integrated circuit optimized for different applications such as comms, signals intelligence (SIGINT), and wideband Electronic Warfare (EW) with access up to 2250 RF states. This chip serves as a prototype for how ART technology can lead the way to life-cycle cost reduction. - Demonstrated advanced concepts for signal recognition at the hardware level and initiate plans for transitioning these approaches to relevant DoD systems. - Demonstrated applicability of tunable filters for dynamic frequency allocation in a fielded radio system. ***FY 2015 Plans:*** - Demonstrate final circuit design technologies including microwave switches, frequency synthesis, and RF functionality. - Demonstrate a fully reconfigurable RF filter element with serial addressing of the components in an appropriate package form factor. - Optimize the RF phase-change switch technology with concentration on reliability along with performing a final RF-FPGA demonstration. - Demonstrate computer aided software flow with advanced fully reconfigurable RF circuit technology at the hardware system level. - Begin integration of a reconfigurable RF front-end system with a reconfigurable, digital back-end system to demonstrate end-to-end reconfigurability after the aperture. ***FY 2016 Plans:*** - Investigate transition plans for a fully reconfigurable RF circuit technology at the component and system levels. - Continue integration of a reconfigurable RF front-end system with a reconfigurable, digital back-end system to demonstrate end-to-end reconfigurability after the aperture.			
Title: Diverse & Accessible Heterogeneous Integration (DAHI) ***Description:*** Prior DARPA efforts have demonstrated the ability to monolithically integrate different semiconductor types to achieve near-ideal "mix-and-match" capability for DoD circuit designers. Specifically, the Compound Semiconductor Materials On Silicon (COSMOS) program enabled transistors of Indium Phosphide (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	31.663	29.400	15.983

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016

level, ultimately offering the seamless co-integration of a variety of semiconductor devices (for example, Gallium Nitride, Indium Phosphide, Gallium Arsenide, 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 for a wide array of system applications.

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 basic research efforts funded in PE 0601101E, Project ES-01, and advanced technology development efforts funded in PE 0603739E, Project MT-15.

FY 2014 Accomplishments:
- Continued to develop 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 three-technology wafer-bonding-based processes for heterogeneous integration, and processes for heterogeneous integration of InP and GaN transistors, Gallium nitride (GaN) MEMS devices, magnetic materials, and microfluidic thermal management structures on silicon and silicon carbide substrates.
- Continued manufacturing, yield and reliability enhancement for multi-user foundry capability based on developed diverse heterogeneous integration processes.
- Continued design and fabrication of high complexity heterogeneously integrated RF/optoelectronic/mixed signal and circuits, such as wide band RF transmitters, advanced mixed signal integrated systems, optoelectronic RF signal sources, and laser-radar systems.
- Completed circuit designs for initial heterogeneous integration multi-project wafer foundry fabrication run, which are currently being fabricated.

FY 2015 Plans:
- Complete 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.

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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
- Complete manufacturing, yield and reliability enhancement for multi-user foundry capability based on developed diverse heterogeneous integration processes. - Complete design and fabrication of high complexity heterogeneously integrated RF/optoelectronic/mixed signal and circuits, such as wide band RF transmitters, advanced mixed signal integrated systems, optoelectronic RF signal sources, and laser radar systems. ***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.			
Title: IntraChip Enhanced Cooling (ICECool) ***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 kilowatt/cm^2 and chip package heat removal density to above 1kilowatt/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 2014 Accomplishments:*** - Prepared and refined initial thermal models of intrachip cooling to explain and predict experimental results. - Demonstrated proof of concept of fundamental building blocks of evaporative intrachip/interchip thermal management including microfabrication in relevant electronic substrates and preliminary thermofluid results. - Designed thermal test vehicles in the form factor of high power amplifiers (HPAs) and high performance computers (HPCs) and demonstrated that embedded microfluidic cooling had the potential to manage heat fluxes of 1 kW/cm^2 and densities of 1 kW/cm^3 through modeling and proof of concept experiments. ***FY 2015 Plans:***	19.500	18.000	17.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Demonstrate the full implementation of the fundamental building blocks of evaporative intrachip/interchip cooling including embedded micron-scale microfluidic channels in Silicon (Si), Silicon Carbide (SiC), and diamond; two-phase flow approaching 95% vapor exit quality, and integrated thin-film thermoelectric devices. - Demonstrate HPAs and embedded HPCs thermal test vehicles that can successfully handle heat fluxes of 1 kW/cm^2, hot spots of 30 kW/cm2 (HPAs) or 2 kW/cm^2 (HPCs), and reduce the thermal resistance of the test vehicle by 3x compared to the State of the Art (SOA) baseline. - Design application-oriented electrical test vehicles to demonstrate the performance benefits of embedded microfluidic cooling and relate these results to system-level performance and size, weight, power and cost (SWaPC) through the use of intrachip thermal management technologies. - Design fully-functional HPAs and HPCs to demonstrate the thermal and electrical performance benefits of embedded microfluidic cooling where the 3x or greater reduction in thermal resistance with 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 prove out mean time to failure and compatibility with relevant Military specifications. - 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 2014 Accomplishments:*** - Achieved a safe in vivo nanoplatform sensor to detect military-relevant analytes (e.g., nucleic acids) in an animal model with a robust signal for at least six months. - Achieved a safe and effective in vivo nanoplatform therapeutic to reduce a military-relevant pathogen in a small animal model.	23.388	14.500	9.765

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Updated regulatory approval pathway of identified safe and effective diagnostic and therapeutic nanoplatforms. ***FY 2015 Plans:*** - Demonstrate 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. - Demonstrate 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. - Update 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, 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.			
Title: Pixel Network (PIXNET) for Dynamic Visualization ***Description:*** The PIXNET program addresses the squad level capability gap for target detection, recognition and identification in all-weather and 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 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 thermal and reflected-illumination bands. The camera will also provide fused reflective and thermal band imagery on demand. 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 capability, allowing detection, recognition and identification of targets from a single camera whether 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 portability and ability to deploy widely to all participants in the theater. The emphasis on a small form will naturally enable new opportunities such as surveillance with small Unmanned Aerial Vehicles (UAV), rifle sights with multiple bands, and vehicle-mounted, helmet-mounted and handheld surveillance systems. The phenomenology of different infrared wavelengths will be exploited. The	23.700	13.000	10.250

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 2014 Accomplishments:*** - Developed and reviewed IR camera design and overall architecture that will demonstrate digital image data transmission and signal processing via wireless connectivity using an android based platform. - Identified parameters required for multicolor helmet-mounted technology for very low SWaP multi-color IR camera. - Completed short wave (SW)/mid-wave (MW) optics design for clip-on weapon sight. - Identified wireless interface protocols for rifles/weapons and helmet displays that are compliant with dismount requirements. - Performed final design of the long-wave IR/very-near IR (LWIR/VNIR) camera cores, optic lens assemblies, display module, image fusion network power components, helmet package, image processing pipeline, and embedded software applications. ***FY 2015 Plans:*** - Demonstrate brass board components for the LWIR/VNIR helmet camera. - Refine algorithms to fuse data from thermal and reflective bands with good image registration. - Complete interim small form-factor camera integration and demonstrate connectivity to heads-up display and Android-based platform. - Complete Readout Integrated Circuit (ROIC) tapeout and SW/MW fabrication. - Complete fabrication of LWIR/VNIR and start final integration of helmet camera. - Demonstrate multicolor image acquisition by interim PIXNET camera, data transmission to Android platform, image fusion by Android platform, and viewing of fused imagery on heads-up display. - Evaluate and refine the multicolor PIXNET camera based on Phase 1 brass-board demonstration. - Update the fusion and rendering algorithms to meet the system requirements. ***FY 2016 Plans:*** - Implement algorithms into final camera and laptop to demonstrate functionality. - Package and integrate multicolor systems into final form factor. - Demonstrate helmet mounted and clip-on weapon sight video on Smart Phone with final camera deliverables.			
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	23.856	25.000	26.550

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
counter adversarial threats under development using commercial-of-the-shelf components that can undergo technology refresh far more frequently. The Arrays at Commercial Timescales (ACT) program will develop adaptive and standardized digital-at-every-element arrays. The hand designed, static analog beamformers will be replaced 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. The basic research component of this program is budgeted under PE 0601101E, Project ES-01. ***FY 2014 Accomplishments:*** - Initiated development of common hardware components for phased-array elements that can be seamlessly integrated into a wide range of platforms and implemented the first iteration of the common components in a state-of-the-art fabrication process. - Initiated the development of digital array systems with performance capabilities that evolve with Moore's law at commercial time scales. - Performed initial characterization of common module data converter components demonstrating high RF sample rates of 64 Giga samples per second. - Demonstrated that non-linear equalization can extend the signal dynamic range by more than 20 decibels. - Initiated the development of electromagnetic (EM) interface elements capable of reconfiguring for various array use cases and operational specifications. - Demonstrated reconfigurability of EM interface components for various array performance specifications and demonstrated compatibility with common digital back-end. - Demonstrated optical actuation of Germanium Telluride phase change switches for reconfigurable antennas with a high on/off ratio of 10,000:1. - Identified government application spaces that could make use of ACT common modules and started discussions with potential transition partners on transition paths to those applications. - Initiated discussions to specify the configuration of the independent government evaluation at the end of the program Phase I. - Conducted Preliminary Design Review (PDR) of ACT Common Module designs. ***FY 2015 Plans:*** - Continue development of application specific integrated circuits (ASIC) in 32 nanometer (nm) CMOS, 65 nm CMOS and Silicon Germanium (SiGe) technologies that enable both commonality across a wide range of platforms and elemental level digital beamforming, the combination of which results in lower cost and faster technology refresh of phased array antenna platforms. - Continue development and integration of common hardware components for a wide range of phased array antenna systems such as application specific integrated circuits, field programmable gate arrays, high data rate, low energy digital buses, high speed connectors, high isolation printed circuit boards, and waste heat removal technologies. - Finalize test plan for independent government common module testing.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Continue the development of EM interface elements capable of reconfiguring for various array use cases and operational specifications, and demonstrate tuning over an octave of bandwidth and over multiple polarization settings. - Continue to demonstrate reconfigurability of EM interface components for various array performance specifications, and demonstrate compatibility with common digital back-end. - Continue to identify government application spaces and transition paths for the ACT Common Module and reconfigurable antenna apertures. - Conduct Critical Design Review (CDR) of ACT Common Module design. ***FY 2016 Plans:*** - Demonstrate the functionality of the common module in a bench-top, laboratory environment. - Demonstrate Common Module hardware viability through government testing of delivered hardware components in a government furnished system platform. - 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 an RF switch, tunable component, or other basic component that will be incorporated into the pixelated array face. - Define the characterization of a switch, tunable component, or other component that is the basis of the antenna system, and create a comprehensive list of projected personalities available from this design. - Continue to identify government application spaces and transition paths for the ACT Common Module and reconfigurable antenna apertures.			
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 beacon. The beacon 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 beacon is meant to be functional on its own, but also a leading indicator of the types of circuits possible under the VAPR program.	9.645	5.500	3.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
To manufacture transient systems at scale will require significant research and development into: higher levels of circuit integration and complexity to realize advanced circuit functionalities; integrated system designs to achieve required function (in modes that offer programmed or triggered transience); integration of novel materials into circuit fabrication processes; and development of new packaging strategies. The efficacy of the technological capability developed through VAPR will be demonstrated through a final test vehicle of a transient sensor system. The goal is to develop a suite of design principles, develop strategies and pathways, process flows, tools and basic components that are readily generalizable and can be leveraged towards the development of many other transient electronics devices. ***FY 2014 Accomplishments:*** - Began developing foundry fabrication of transient electronics with key functions (RF, memory, digital logic, power supply, etc.). - Began developing increased circuit integration and complexity to implement advanced functionalities. - Initiated transient sensors and power supply strategy development. - Began developing transient device fabrication approaches. - Initiated transience mode demonstration in test vehicles. ***FY 2015 Plans:*** - Achieve a transience time of less than or equal to 5 minutes for simple electronic devices. - Reduce the variability of transience time to less than or equal to 90 seconds for simple electronic devices. - Demonstrate capability to have reliable operation of simple transient electronic devices for greater than 24 hours after deployment, with 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 sensors with RF link. - 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.			
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	2.000	2.000	1.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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. 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 processor chip on a silicon platform capable of hybrid electronic-photonic track-and-hold functionality and coherent photo-detection. These silicon photonic integrated circuits will be integrated with complementary metal-oxide semiconductor (CMOS) driver circuits and packaged for integration in the full DISARMER system. This program has advanced technology development efforts funded in PE 0603739E, Project MT-15. ***FY 2014 Accomplishments:*** - Completed research culminating in the design of a photonic processor chip incorporating waveguides, optical phase shifter and balanced photo-detectors. - Demonstrated initial mode locked laser design operating at 8 GHz repetition rate with < 5 fs of integrated timing jitter. ***FY 2015 Plans:*** - Incorporate micro-ring resonator into mode-locked laser design to further reduce jitter. - Fabricate and test the building blocks of the photonic processor, including high-speed, high-power photodetectors and 90 degree phase shifters. - Package photonic processor chip and electronic integrated circuit chip to achieve low parasitic capacitance and inductance between the two chips. ***FY 2016 Plans:*** - 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.			
Title: Hyper-wideband Enabled RF Messaging (HERMES)* ***Description:*** *Formerly Gargoyle Modern weapons systems are dependent on radio frequency (RF) links for communications, command and control of unmanned vehicles, GPS signals and battle management. This dependence will only grow with the move to disaggregated systems in the battlefield. Spectral allocations for these critical RF links confine operations to narrow bands that can be disrupted with commercial hardware. To create assured RF links in the congested battlefield, HERMES will study the architectures and develop the technologies to enable links with 10 GHz of instantaneous bandwidth >40 dB of processing gain. This program will explore the limits of	-	2.000	3.000

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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
processing gain and the potential for tunable filtering within the band to remove narrow-band jammers. HERMES addresses two technical areas covering electronic and hybrid electronic-photonic solutions. ***FY 2015 Plans:*** - Perform analysis and simulation of frequency-dependent channel propagation effects with associated mitigation methods; define the operational envelope and constraints for such a system to include representative electromagnetic background environments, friendly and enemy interferers and multiuser operational environments. - Define system architecture to include wireless RF transmitter and receiver architectures with specifications flowed down to the subsystem and component level. ***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.			
Title: Fast and Big Mixed-Signal Designs (FAB) ***Description:*** 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. This program will investigate the potential for a truly process-agnostic integration technology that is inclusive of any current or future circuit fabrication technology such as GaAs, GaN and SiGe with a standardized interconnect topology. Such a technology platform will enable the design of individual circuit IP blocks, such as low-noise amplifiers and analog-to-digital converters, with a goal of re-use of the intellectual property (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, FAB 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.	-	4.000	10.800

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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
In the Applied Research part of this program, focus will be placed on the rapid development and insertion of microsystems utilizing SiGe technology with 14nm Si CMOS. The development of a SiGe fabrication process 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 Plans:*** - Determine the best choices for the RF and digital technologies and the best methods of co-integration (monolithic, through-silicon via (TSV)s, interposer, etc.) in order to achieve program objectives, along with identifying partner(s) for fabrication and/or integration. - Begin circuit design activities to determine performance benefits of new processes enabled by the program. - Study the best technology for various RF functional blocks for optimal use of mixed technologies. ***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)s, interposer, etc.) in order to achieve program objectives, along with identifying partner(s) for fabrication and/or integration. - Continue circuit design activities to determine performance benefits of new processes enabled by the program. - Continue to study the best technology for various RF functional blocks for optimal use of mixed technologies.			
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 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.	-	3.000	8.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 Plans:*** - Initiate design of DODOS system architecture. - Prototype and test high-bandwidth optical comb sources. - Prototype and test widely-tunable output laser sources. ***FY 2016 Plans:*** - Develop DODOS system architectures and integration approaches. - 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.			
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, exploit, and deny our adversaries use of the electromagnetic (EM) spectrum. The future ability to control the spectrum and deliver non-kinetic effects requires the development of advanced electronic components. HAVOC seeks to strengthen and maintain our dominance of the EM spectrum and overmatch rapidly emerging threats by providing unprecedented electronic attack capabilities by developing a wideband and agile waveform high-power vacuum amplifier. 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 with minimal collateral damage. Realization of high power vacuum-electronic amplifier technology will require significant advancements in high current-density, long-life cathodes, wide band interaction circuits, high-power drivers, low-loss RF windows, and advanced power supplies. Such an electronic component will also bring new capabilities to air, ground, and ship-based radar systems. ***FY 2016 Plans:*** - Initiate the design of a wide-bandwidth, high power microwave vacuum electronic amplifier and identify specific component performance parameters and engineering tradeoffs. - Design, fabricate, and test high current-density cathodes capable of producing beam current consistent with amplifier output power requirements.	-	-	12.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- 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.			
Title: Next Generation Atomic Clock (NGAC) ***Description:*** 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 wide availability of atomic-quality timing in portable battery-powered applications. The Next-Generation Atomic Clock (NGAC) program will develop a next-generation chip-scale 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. NGAC will develop chip-scale atomic clocks achieving temperature coefficient of frequency of 10^-15/degrees Celsius and drift < 10^-12/month. This will enable precise timing on low cost, size, weight, and power (CSWaP) platforms with extended mission duration. In order to achieve these performance metrics, new enabling technology and interrogation techniques will be integrated into systems and proven to operate on a moving platform. Basic research for this program is funded within PE 0601101E, Project ES-01. ***FY 2016 Plans:*** - Demonstrate prototype clock operation utilizing low-CSWaP component technology. - Evaluate environmental sensitivity, particularly temperature and acceleration. - Identify technology gaps and complete a roadmap for NGAC development.	-	-	8.400
Title: Precise Robust Inertial Guidance for Munitions (PRIGM) ***Description:*** The Precise Robust Inertial Guidance for Munitions (PRIGM) program will develop low-Cost, Size, Weight, and Power (CSWaP) inertial sensor technology for GPS-free munitions guidance. 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	-	-	10.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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 2014	FY 2015	FY 2016
MEMS technology to realize novel inertial sensors for application in extreme dynamic environments and beyond navigation-grade performance. 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 suffers from large parasitics, temperature sensitivity, and gas damping from narrow gaps. While various methods have been used to overcome challenges with capacitive readout, optical sensing has demonstrated potential for high sensitivity, low noise, and robust inertial sensing. Recent advances in heterogeneous integration, on-chip optical waveguides, and quantum-assisted sensing and readout demonstrate potential for optically interrogated MEMS enabled gyros/accelerometers (OMEGA), interferometric and resonant photonic waveguide optical gyros (iWOG/rWOG), and whole angle gyros (WAG) that reach fundamental measurement limits. Fully integrated opto-MEMS inertial sensors may comprise stiffer mechanical structures that are thus capable of higher shock, vibration, and temperature tolerance along with improved navigation performance. Advanced research for the program is budgeted in PE 0603739E, Project MT-15. ***FY 2016 Plans:*** - Model and design architectures for chip-scale optical gyroscopes based on waveguide technologies - Design and fabricate heterogeneously-integrated, chip-scale waveguide optical gyroscopes - Demonstrate high-bandwidth (100,000 degrees/s) inertial sensors - Model and design optically interrogated MEMS inertial sensors - Develop co-fabrication processes to support MEMS optical interrogation - Demonstrate shock survivability of sensors and component technologies			
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 (SOA) 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 or ultimately by the battery self-discharge. The Near Zero Energy RF and Sensor Operations (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 energy devices. The N-	-	-	4.500

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 only 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 communications and sensors systems with massively reduced size and drastically increased mission life. The basic research component of this program is budgeted under PE 0601101E, Project ES-01. ***FY 2016 Plans:*** - Initiate development of hardware components enabling passive or near zero energy collection, processing and detection of communications and sensor information. - Initiate development of RF and physical sensor microsystems that collect, processes and detect the presence of desired signals while consuming near zero power. - Identify government application spaces and transition paths that will make use of N-ZERO signal processing and detection.			
Title: Microwaves and Magnetics (M&M) ***Description:*** Passive magnetic components such as frequency selective limiters (FSL), isolators, circulators, phase shifters and filters are integral to numerous military electronic systems in applications including radar, imaging, communications, and electronic warfare. However, the rate of development and level of integration in microwave and mm-wave magnetic components have severely lagged the corresponding advancements and monolithic integration of semiconductor, microelectromechanical systems (MEMS), and optical active devices. In some cases the magnetic technologies have changed little in the past 20 to 30 years. The Microwaves and Magnetics program will leverage advanced magnetic components leading to disruptive improvements in system performance and novel functionality; and it will drive advances in materials science, materials processing, and in component design, modeling, integration, and fabrication leading to disruptive technologies that will ensure control of the electromagnetic (EM) spectrum. This targeted program in advanced and integrated RF/microwave magnetic components will enable the improvements needed for the next generation of DoD electronic systems. This program has advanced technology development efforts funded in PE 0603739E, Project MT-15. ***FY 2016 Plans:*** - Investigate recent advances in magnetic materials science to identify new processing, fabrication, and integration techniques that can enable microwave components with reduced loss, increased bandwidth, and enhanced tunability. - Leverage new microwave component design and modeling techniques to assess the performance of advanced magnetic materials in microwave circuits and applications. - Initiate the design and development of magnetic components using advanced magnetic materials with reduced loss, increased bandwidth, and enhanced tunability.	-	-	5.000
Title: MultiPLEX	-	-	8.000

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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
Description: Dominance of the electromagnetic spectrum is a central pillar of modern warfare. As carrier frequencies of signals continue to increase, our traditional RF systems encounter difficulties with capturing and processing them. Capturing wide swaths of the spectrum simultaneously using traditional electronic technology is too large and too power hungry for virtually any DoD platform. Photonic technology has reached a maturity where it can offer a solution by providing low-loss, chip-scale components with the necessary linearity and noise figure that RF systems demand. MultiPLEX will deliver a chip-scale channelized receiver covering 20 - 50 GHz in 200 MHz-wide channels with 12 effective bits of resolution. The program will focus on the design and build of a hybrid electronic-photonic system that encompasses the entire receiver, from the low noise amplifier to the analog-to-digital converter. The program will develop high-Q optical filters and on-chip photonic mixing with high spur free dynamic range. The fully integrated channelized receiver will impact signals intelligence and electronic warfare systems and demonstrate the feasibility and utility of integrated photonics for RF applications. ***FY 2016 Plans:*** - Design and simulate the complete channelized receiver and generate flow down specifications to component technologies. - Demonstrate the high risk photonic components in a high yield, repeatable fabrication process compatible with silicon manufacturing.			
Title: Diamond Enhanced Devices (DiamEnD) ***Description:*** Diamond Enhanced Devices (DiamEnD) will further unlock the potential of Gallium Nitride (GaN) High-electron-mobility transistors (HEMTs) in defense electronics by removing the thermal limitation on performance through replacement of the original substrate with high conductivity (optical quality) diamond. Today, state-of-the-art (SoA) GaN HEMTs used in monolithic microwave integrated circuits (MMICs) reside on moderate thermal conductivity Silicon Carbide (SiC) substrates, which thermally limit the linear power density to between 5 W/mm and 7 W/mm, well below the ultimate limits achieved in pulsed power RF experiments. Through the incorporation of diamond as the substrate and subsequent increase in transistor drain voltage, this linear power density can be boosted to 15-25 W/mm in devices with existing SoA GaN epitaxy layer and as high as 40-60 W/mm with further epitaxial material and transistor development. These DiamEnD devices can then be used to substantially increase output power or reduce system Size, Weight, and Power (SWAP). This increased power density will be the heart of future long range RF engagements, either for smaller systems using the increased power density in a small aperture, or by larger systems which will be able to engage at even longer ranges or faster search speeds. ***FY 2016 Plans:*** - Demonstrate that GaN epitaxy can be harvested from the SOA GaN on SiC epitaxy developed in the Wide Band Gap Semiconductors (WBGS)-RF program and mated with diamond substrates. - Initiate effort to develop the diamond substrate materials and transistor technology to demonstrate GaN on Diamond devices with up to 25 W/mm.	-	-	6.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Initiate effort to modify GaN epitaxy and modify transistor structures to have GaN material that can be used to make devices that can reach 40-60 W/mm.			
Title: Micro-Technology for Positioning, Navigation, and Timing (Micro PN&T)	19.736	13.500	-

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.

The successful realization of Micro-PNT depends on the 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 includes 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 includes 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 2014 Accomplishments:
- Demonstrated rotational sensitivity of prototype miniature inertial sensors based on modern atomic physics techniques.
- Demonstrated pulsed nuclear magnetic resonance gyroscopes.
- Demonstrated electronic and algorithmic self-calibration of MEMS gyroscopes to achieve better than 100 ppm long-term stability of scale factor and bias.
- Demonstrated a three-axis MEMS inertial sensor with total device volume < 10 mm^3.
- Explored novel, enabling technologies for atom physics based devices (ex: magnet-free ion pump, shutter technology, alkali vapor pressure control).

FY 2015 Plans:
- Demonstrate on-chip MEMS calibration stages to track bias and scale factor stability repeatable to <100 ppm.
- Demonstrate a miniaturized, low-drift Nuclear Magnetic Resonance (NMR) gyroscope.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Fabricate low loss shell resonators for gyroscope applications with ringdown time > 100 seconds. - Demonstrate novel, enabling technologies for atom physics based devices (ex: magnet-free ion pump, shutter technology, alkali vapor pressure control)			
Title: Terahertz Electronics ***Description:*** The Terahertz Electronics program is developing 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 is divided into two major technical activities: Terahertz Transistor Electronics that includes the development and demonstration of materials and processing technologies for transistors and integrated circuits for receivers and exciters that operate at THz frequencies; and Terahertz High Power Amplifier Modules that includes the development and demonstration of device and processing technologies for high power amplification of THz signals in compact modules. ***FY 2014 Accomplishments:*** - Completed circuit demonstrations between 0.67 THz and 0.85 THz, including high power amplifiers and integrated circuits. - Improved process yield of 0.67 THz transistors and demonstrated key building blocks for 0.67 THz heterodyne detectors and sensors. - Completed design and initiated fabrication of a 1.03 THz vacuum amplifier. - Demonstrated world's first THz Monolithic Microwave Integrated Circuit (MMIC) amplifier, which produced 10dB of gain at 1.0 THz. ***FY 2015 Plans:*** - Complete measurements of receiver/exciter technologies at and above 0.67 THz. - Demonstrate oscillator circuits at 1.03 THz. - Demonstrate prototype THz transceiver link using THz Indium Phosphide (InP) technology. - Demonstrate a 1.03 THz vacuum amplifier. - Demonstrate improved thermal performance of vacuum amplifier for high duty cycle operation at THz frequencies.	14.250	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 will enable 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 is 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	7.480	4.280	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 will be reproducible, high-yield, high-uniformity, and highly reliable. The accomplishment of this goal will be 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 technology will be the speed, linearity, and power efficiency improvement of RF and mixed-signal electronic circuits used in military communications, electronic warfare and sensing. ***FY 2014 Accomplishments:*** - Completed enhancement / depletion mode transistor scaling development for fully self-aligned nitride transistors with full process compatibility. - Initiated development of NEXT process design kit for circuit designers. - Designed and fabricated RF signal demonstration circuits based on latest NEXT transistors and integration processes. ***FY 2015 Plans:*** - Establish the baseline of the high-speed / high breakdown voltage NEXT fabrication technology with high reproducibility and yield. - Design, fabricate, and test military-relevant circuits, such as RF power amplifiers, using the developed NEXT transistor technology. - Update NEXT process design kit to allow external 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 is to design, develop, and characterize MPD technologies, circuits, and substrates. The MPD program will focus 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 will be 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. It is envisaged that both two and multi-terminal devices consisting of various architectures will be developed and optimized under the scope of this program. MPDs will be 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 MPD applied research program is 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. It is expected that	5.310	2.000	-

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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
the MPD program will result 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 2014 Accomplishments:*** - Continued integration of multiple simulation efforts into the modeling-and-simulation design tool (MSDT) for commercial development of microplasma based electronics and DoD systems. - Optimized plasma microcavity materials for DoD systems of interest, demonstrating robust electronic protection in high power electromagnetic environments. - Demonstrated and tested nonlinear signal processing circuit devices and architectures based on MPD technologies. ***FY 2015 Plans:*** - Complete integration of the simulation efforts into the MSDT for commercial development of microplasma based electronics. - Complete 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. - Complete demonstration of plasma-based materials and devices in representative system applications for transition to multiple DoD customers.			
Title: Micro-coolers for Focal Plane Arrays (MC-FPA) ***Description:*** The Micro-coolers for Focal Plane Arrays (MC-FPA) program will develop low Size, Weight, Power, and Cost (SWaP-C) cryogenic coolers for application in high performance IR cameras. 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 Stirling cryo-coolers used for high performance IR FPAs are 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 will exploit the Joule-Thomson (J-T) cooling principle, in a silicon-based MEMS technology, for making IR FPA coolers with very low SWaP-C. MEMS microfluidics, piezoelectric MEMS, and complementary metal-oxide semiconductor (CMOS) electronics will be used to demonstrate an integrated cold head and compressor, all in a semiconductor chip. Since a J-T cooler works by cooling from gas expansion, the coefficient of performance is expected to be much higher than state-of-the-art TE coolers, while being significantly smaller than Stirling coolers. The chip-scale J-T cooler will be designed for pressure ratios of four or five to one with high compressor frequency in a small volume. The goal of the MC-FPA program will be to demonstrate cooling down to 150 K. The chip-scale micro-coolers will cost less and will be significantly smaller than current Stirling coolers. Once the proof-of-principle is demonstrated, the subsequent program effort will focus on transitioning to chip-scale manufacture on eight to twelve inch wafers, resulting in cooler costs decreasing to as low as $50. An extended wavelength-range short-wave IR detector will	2.450	1.000	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
be integrated with a micro-cooler for demonstration of the MC-FPA. The basic research component of this program is budgeted under PE 0601101E, Project ES-01. ***FY 2014 Accomplishments:*** - Developed detector design for response in 1-2.4 micrometers. - Performed materials growth and characterization for detector fabrication. - Processed Cadmium Zinc Telluride (CdZnTe) substrates for epitaxy. - Completed initial analysis to determine input cell design for readout integrated circuit (ROIC). - Developed 640X480 extended shortwave infrared (1-2.4 micrometer cutoff) FPA. - Designed a readout integrated circuit (ROIC) for the IR FPA chip. - Demonstrated camera electronics for the FPA with provision for chip-scale micro-cooler. ***FY 2015 Plans:*** - Evaluate 3-stage J-T micro-cooler. - Hybridize FPA to ROIC, integrate 3-stage J-T micro-cooler, and test. - Evaluate 5-stage J-T micro-cooler. - Hybridize FPA to ROIC and integrate 5-stage J-T micro-cooler with complete backend packaging. - Complete camera integration and housing. - Complete camera tests and demo. - Final camera delivery and program close out.			
Title: Microscale Power Conversion (MPC) ***Description:*** Today's power amplifiers utilize large, bulky, independently designed fixed voltage power supplies that fundamentally limit RF system output power, power efficiency and potential for integration. The Microscale Power Conversion (MPC) program developed X-band RF transmitters as system-in-package modules, in which integrated circuit power amplifiers were integrated with dynamic, variable voltage power supplies using high-speed power switches. Such an integrated microsystem supports military applications requiring several hundred Megahertz (MHz) of RF envelope bandwidth at large peak-to-average power ratios. This integration approach realized RF systems with significantly higher overall power efficiency and waveform diversity by changing from fixed power supply architecture to dynamic power supply architecture. The program was structured in two technical tracks. The first track developed high-speed power switch technology to be used in the design of dynamic power supply and modulator circuits. The second track developed the simultaneous co-design and integration of the RF power amplifier and dynamic power supply circuits to achieve maximum overall power efficiency for the desired waveforms of interest. The program enabled increased deployment of MPC RF transmitter systems on DoD platforms due to their more compact size, high efficiency, lower lifecycle cost and enhanced RF performance enabling, for example, significantly communications rates.	8.800	-	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
FY 2014 Accomplishments: - Completed very high frequency, low-loss power switch technology for implementing large envelope-bandwidth modulators for RF power amplifiers. - Demonstrated final co-designs of advanced X-band transmitter including drain and gate bias modulation, dynamic output impedance matching, and closed-loop control with fast-switching power modulation. - Furnished power switch process design kits to DoD contractors for use in future power supply modulator or power amplifier designs.			
Title: Photonically Optimized Embedded Microprocessor (POEM) ***Description:*** Based upon current scaling trends, microprocessor performance is projected to fall far short of future military needs. Microprocessor performance is saturating and leading to reduced computational efficiency because of the limitations of electrical communications. The POEM program demonstrated chip-scale, silicon-photonic technologies that can be integrated within embedded microprocessors for seamless, energy-efficient, high-capacity communications within and between the processor chip and dynamic random access memory (DRAM) chip. This technology propelled microprocessors onto a higher performance trajectory by overcoming this "memory wall". ***FY 2014 Accomplishments:*** - Demonstrated a photonic link between two Silicon-on-Insulator-Complementary-metal-oxide-semiconductor (SOI-CMOS) DRAM chips consuming 1.3 (2.8) pJ/bit employing foundry-compatible photonic devices and respective control and driver circuits. - Fabricated and tested optical receiver circuits with 31 nanoseconds (ns) locking time and consuming 5.4 pJ/bit operating at 25 Gb/s. - Designed new algorithms that effectively parallelize graph analytic problems (e.g. community analysis and shortest path), taking advantage of the high bandwidth photonic interconnects. - Designed and optimized material stack for fabricating an on-chip, uncooled laser operating at 1550 nm with >7% wall plug efficiency at 80C.	1.500	-	-
Accomplishments/Planned Programs Subtotals	222.287	169.203	174.798

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

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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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	146.789	129.723	185.043	-	185.043	193.011	176.089	187.521	189.156	-	-
AIR-01: *ADVANCED AEROSPACE SYSTEMS*	-	146.789	129.723	185.043	-	185.043	193.011	176.089	187.521	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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	144.804	129.723	178.043	-	178.043
Current President's Budget	146.789	129.723	185.043	-	185.043
Total Adjustments	1.985	-	7.000	-	7.000
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	5.923	-			
• SBIR/STTR Transfer	-3.938	-			
• TotalOtherAdjustments	-	-	7.000	-	7.000

Change Summary Explanation

FY 2014: Increase reflects reprogrammings offset by the SBIR/STTR transfer.

FY 2016: Increase reflects maturation of the Vertical Take-Off and Landing (VTOL) Technology Demonstrator and subsequent transfer from Budget Activity 2 to the Advanced Aerospace Systems Program Element, offset by completion of the Aerial Reconfigurable Embedded Systems (ARES) and Persistent Close Air Support (PCAS) programs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Tactically Exploited Reconnaissance Node (TERN)	20.934	30.000	22.000

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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 2014	FY 2015	FY 2016
Description: The goal of the Tactically Exploited Reconnaissance Node (TERN) program, a joint effort with the Office of Naval Research, is to develop a systems approach for, and perform technical demonstration of, a Medium-Altitude, Long-Endurance Unmanned Aerial Vehicle (MALE UAV) capability from smaller ships. The program will demonstrate the technology for launch and recovery of large unmanned aircraft capable of providing persistent 24/7 Intelligence, Surveillance, and Reconnaissance (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 2014 Accomplishments:*** - Defined the launch and recovery technique through evaluations and trade studies. - Completed studies on integration with existing Service systems and systems architectures. - Studied aircraft design trades and approaches to best meet performance goals at minimum lifecycle cost. - Began development of simulation and control schemes to achieve high precision approach. - Identified equipment and interface requirements for ship launch and recovery systems. - Initiated risk reduction simulations and testing. ***FY 2015 Plans:*** - Continue technology maturation and complete preliminary design. - Continue integrated aircraft risk reduction simulations and testing. - Initiate subscale testing of propulsion system. - Commence integrated ship-aircraft simulation activity. - Conduct large-scale demonstration of select technology development elements. ***FY 2016 Plans:*** - Commence procurement of long-lead demonstrator system components. - Complete detailed design of demonstrator aircraft. - Begin fabrication and testing of demonstrator system hardware. - Complete subscale testing of propulsion system. - Initial testing of ship relative navigation system.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Perform subsystem risk reduction demonstrations.			
Title: Collaborative Operations in Denied Environment (CODE)	8.000	25.000	27.043
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 though autonomy and collaborative behaviors, within a standard based open architecture. Potential transition partners include the Air Force, Army, and Navy. ***FY 2014 Accomplishments:*** - Initiated systems engineering phase, selected candidate missions, and defined security framework. - Began work on open architecture for distributed system and very low communication constraints. ***FY 2015 Plans:*** - Perform trade studies and decompose selected missions. - Develop collaborative algorithms, autonomous tactics, concepts for communication, and supervisory interface. - Develop software module specifications compliant with standard based open architecture including OSD unmanned aircraft system control segment. - Evaluate algorithms, tactics, communication and interfaces, in high fidelity non-real time simulation against key performance parameters. ***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 vehicle level autonomy, including on-board real time sensor processing, contingency management, and complex flight path 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.			

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Evaluate algorithms, tactics, communication and interfaces, in non-real time simulation.			
Title: Hypersonic Air-breathing Weapon Concept (HAWC)	15.200	5.500	40.000

Description: The Hypersonic Air-breathing Weapon Concept (HAWC) program is a Joint DARPA / Air Force effort that will develop and demonstrate technologies to enable transformational changes in responsive, long-range strike against time-critical or heavily defended targets. HAWC will pursue flight demonstration of the critical technologies for an effective and affordable air-launched hypersonic cruise missile. These technologies include advanced air vehicle configurations capable of efficient hypersonic flight, hydrocarbon scramjet-powered propulsion to enable sustained hypersonic cruise, thermal management approaches designed for high-temperature cruise, and affordable system designs and manufacturing approaches. HAWC technologies also extend to reusable hypersonic air platforms for applications such as global presence and space lift. The HAWC program will leverage advances made by the previously funded Falcon, X-51, and HyFly programs. This is a joint program with the Air Force, and HAWC technologies are planned for transition to the Air Force after flight testing is complete.

FY 2014 Accomplishments:
- Conducted hypersonic air-breathing missile objective system trades studies and conceptual design definition.
- Derived hypersonic air-breathing missile demonstration system design from the objective system and began developing the suite of enabling technologies.
- Began developing flight testing plans for the hypersonic air-breathing missile demonstrator.
- Initiated risk reduction testing of enabling subsystem technologies for the hypersonic air-breathing missile demonstrator.

FY 2015 Plans:
- Continue risk reduction testing of subsystem technologies for hypersonic air-breathing missile demonstrator.
- Complete technology demonstration system requirements review and initiate preliminary design of hypersonic air-breathing missile flight demonstration system.
- Conduct full-scale freejet propulsion system design and fabrication and initiate testing.
- Initiate 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.
- Begin fabrication and testing of thermal protection system materials.
- Begin detailed design of the hypersonic air-breathing missile flight demonstration system.
- Begin test-validated performance databases to anchor demonstration vehicle design.
- Conduct final full-scale freejet propulsion system testing.
- Complete software architecture and algorithm design, and begin software-in-the-loop testing for the demonstration vehicle.
- Begin procurement of long lead hardware for hypersonic air-breathing missile flight demonstration vehicle.

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Initiate flight certification reviews with the test range. - Continue detailed plans for flight testing of the air-breathing missile demonstration system.			
Title: Tactical Boost Glide	20.000	15.000	20.000
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 a 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 2014 Accomplishments:*** - Completed trade space analysis for tactical range hypersonic boost glide systems. - Began development of TBG Concept of Operations (ConOps). - Began development of TBG Operational System (OS) conceptual designs and system capabilities. - Completed a baseline operational analysis of the Government Reference Vehicle (GRV). - Began operational analysis of the TBG performers operational systems. - Began booster range and energy management study. - Began aerodynamic and aerothermodynamic GRV risk reduction testing. ***FY 2015 Plans:*** - Complete TBG ConOps, Operational System conceptual design reviews and system capability documentation. - Complete operational analysis of the performer TBG operational systems. - Complete operational analysis of evolved GRV. - Complete TBG Demonstration System conceptual design and systems requirements reviews. - Complete initial Technology Maturation Plans (TMPs). - Complete initial Risk Management Plan (RMP). - Select booster and launch platforms. - Conduct initial test range and range safety coordination. - Begin Phase I aerodynamic and aerothermal concept testing. - Begin development of first generation aero databases.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Complete aerodynamic and aerothermal GRV risk reduction testing. - Complete booster range and energy management study. ***FY 2016 Plans:*** - Select TBG demonstration test range. - Develop initial flight test plan. - Complete Preliminary Design Reviews (PDR). - Complete first generation aero databases. - Continue risk reduction and qualification testing. - Begin TBG concept refinement testing.			
Title: Aerial Reconfigurable Embedded System (ARES) ***Description:*** Current and future land and ship-to-shore operations will require rapid and distributed employment of U.S. forces on the battlefield. The Aerial Reconfigurable Embedded System (ARES) program will develop a vertical take-off and landing (VTOL), modular unmanned air vehicle that can carry a 3,000 lb useful load at a range of 250 nautical miles on a single tank of fuel. ARES will enable distributed operations and access to compact, high altitude landing zones to reduce warfighter exposure to hostile threats and bypass ground obstructions. ARES modular capability allows for mission modules to be quickly interchanged and deployed at the company level. This enables the flexible employment of many different capabilities including: cargo resupply, casualty evacuation, reconnaissance, weapons platforms, and other types of operations. ARES vehicles could be dispatched to resupply isolated small units. ARES is well suited for enhanced company operations concepts that would provide the warfighter/team increased situational awareness for operations in an urban environment. The enabling technologies of interest being developed under the ARES program include vertical and translational flight, conversion between powered lift and wing borne lift, ducted fan propulsion systems, lightweight materials, tailless configuration, modularity, and advanced flight controls for stable transition from vertical to horizontal flight. Additionally, the program will explore opportunities for the design, development, and integration of new, key technologies and capabilities. These include adaptable landing gear concepts to enable operations from irregular landing zones and moving launch/recovery platforms, and autonomous take off and landing. The anticipated transition partners for this effort are the Army, Marine Corps, and Special Operations Forces. ***FY 2014 Accomplishments:*** - Completed Critical Design Review for the ARES system. - Fabricated custom components, acquired powerplant and drivetrain components. - Performed one third scale powered tunnel test of flight module with cargo module. - Conducted component testing and static propulsion testing, showing feasibility and function of critical technology components.	31.000	25.000	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Updated flight control software using tunnel data with cargo module control derivatives. ***FY 2015 Plans:*** - Complete drive train testing with flight components. - Complete development of flight control software to ensure successful flight and ground testing. - Conduct subsystem testing and integration of components into the full scale prototype ARES system. - Complete hardware-in-the-loop and software-in-the-loop testing with fully integrated full scale prototype ARES system. - Conduct a test readiness review in preparation for ground and test demonstrations of the prototype vehicle. - Conduct ground demonstrations of the prototype vehicle in preparation for flight testing. - Conduct flight tests to demonstrate that the vehicle meets program objectives by flying with and without a cargo module to show cargo delivery. - Continue flight test to validate flight envelope and expand speed and altitude performance. - Conduct demonstration flights for communities of interest.			
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. ***FY 2014 Accomplishments:*** - Initiated study for the integration of hypersonic propulsion technologies, and a flowpath assessment for engine mode transition. - Validated sub-system performance and conducted sub-system risk reduction testing. ***FY 2015 Plans:*** - Completed hypersonic propulsion integration and flowpath assessments. - Initiate studies of emerging concepts. ***FY 2016 Plans:*** - Perform feasibility experiments of candidate technologies and system concepts.	6.000	4.510	3.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Conduct trade studies and modeling and simulation for novel technologies.			
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. ***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. - Create a technology development and system attributes demonstration roadmap. - Develop and refine the final unmanned vehicle design and concept. - Perform system and system-of-system trades.	-	-	12.000
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, and a lift-to-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. 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	-	-	48.000

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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. ***FY 2016 Plans:*** - Complete subscale model flight testing for flight controls verification and validation. - Complete preliminary design of all subsystems. - Complete system preliminary design reviews and select performer for detailed design, fabrication, and flight test. - Conduct detailed analyses and design refinements for all subsystems. - 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.			
Title: Persistent Close Air Support (PCAS) ***Description:*** The Persistent Close Air Support (PCAS) program will significantly increase close air support (CAS) capabilities by developing a system to allow continuous CAS availability and lethality to the supported ground commander. The enabling technologies are: manned/unmanned attack platforms, next generation graphical user interfaces, data links, digital guidance and control, and advanced munitions. PCAS will demonstrate the ability to digitally task a CAS platform from the ground to attack multiple/simultaneous targets. PCAS will allow 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 will be designed to reduce collateral damage and potential fratricide to friendly forces. The anticipated transition partners are the Air Force, Special Operations Command, and the United States Marine Corps. ***FY 2014 Accomplishments:*** - Performed ground test of A-10 demonstration aircraft architecture, networking, and avionics. - Completed hardware/software fabrication and field tested prototype PCAS kit for dismounted JTAC. - Conducted technical readiness review of PCAS aircraft systems and JTAC kit. ***FY 2015 Plans:*** - Prepare for and commence live fire demonstrations of PCAS prototype system. - Complete flight testing of PCAS prototype system. - Transition elements of PCAS air and ground systems to targeted Service partners.	26.108	24.713	-
Title: Distributed Fires (DFires)	-	-	6.000

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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
Description: The goal of the Distributed Fires (DFires) program is to create a capability which would allow for precision fires from extended ranges (>500 km) to be rapidly accessed by lower echelon units. The DFires system would be a stand-alone system that would be transported by light trucks, rotorcraft, or small boats and delivered to supporting locations on the battlefield. Small units would use tactical radios to call for support fire which would greatly shorten the time required to receive artillery fire or to call in close air support. The modular base 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. As envisioned, different stores could be developed that would enable the small unit to rapidly access different capabilities. For example, in a direct fire mission, target information would be fed to a fast missile which would engage the target at that location. Alternatively, an Intelligence, Surveillance and Reconnaissance (ISR) request could be quickly accomplished by launching a loitering munition which would rapidly fly to the requested area and loiter while feeding ISR data to the warfighters. A loitering attack munition could also be called which would loiter in an area while searching for a target or waiting for final targeting commands. Technology areas to be developed include the overall system architecture, the communications requirements and protocols, and specific stores. ***FY 2016 Plans:*** - Conduct trade space analysis and develop overall system architecture. - Preliminary design of multiple types of onboard stores. - Develop communications architecture and targeting protocols.			
Title: Multi-Domain Unmanned System (UxS) ***Description:*** The Multi-Domain UxS program will develop capabilities to enable both individual and teams of unmanned systems to span the various physical domains (ground-air, ground-sea, air-sea). The purpose of the Multi-Domain UxS is to enable affordable and efficient disruptive capabilities that the U.S. military does not possess today. The program will develop morphing, cross domain structures (mechanical and hydrodynamic) utilizing efficient power and propulsion systems. It will leverage emerging collaborative algorithms and approaches, while developing novel attachment and detachment mechanisms to support cross domain sensing, traversal, and mission execution. The systems prototype will demonstrate deployment from one domain and then modification in deployment to execute missions in another physical domain. ***FY 2016 Plans:*** - Conduct systems architecture trades and cost studies. - Initiate design studies of candidate systems.	-	-	7.000
Title: Long Range Anti-Ship Missile Demonstration (LRASM) ***Description:*** In response to emerging threats, DARPA built upon recent technology advances to develop and demonstrate standoff anti-ship strike technologies to reverse the significant and growing U.S. naval surface strike capability deficit. The Long	14.547	-	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Range Anti-Ship Missile (LRASM) program invested in advanced component and integrated system technologies capable of providing a dramatic leap ahead in U.S. surface warfare capability focusing on organic wide area target discrimination in a network denied environment, innovative terminal survivability in the face of advanced defensive systems, and high assurance target lethality approaches. Specific technology development areas included: robust precision guidance, navigation and control with GPS denial, multi-modal sensors for high probability target identification in dense shipping environments, and precision aimpoint targeting for maximum lethality. Component technologies were developed, demonstrated, and integrated into a complete weapon system. The program resulted in a high fidelity demonstration to support military utility assessment. LRASM is a joint DARPA/ Navy effort that has transitioned to a program of record. ***FY 2014 Accomplishments:*** - Completed missile and canister integration for a surface launched system. - Completed subsystem testing to reduce risks of integration, interference, and flight failure. - Validated booster adapter and separation device designs through analysis and testing. - Completed ground test vehicle end-to-end simulation testing for successful flight predictions. - Finalized supporting documentation including flight test and safety plans in preparation for flight demonstration. - Completed final integration and checkout of controlled test vehicle in preparation for flight testing. - Completed end-to-end system flight demonstration. - Performed one controlled test vehicle flight from the vertical launching system. - Validated system performance via free flight test event. - Completed end-to-end system flight demonstrations on final test missiles.			
Title: Next Generation Air Dominance Study ***Description:*** The Next Generation Air Dominance study defined the projected threat domains and capability gaps for the 2020-2050 timeframe. DARPA conducted a study of current air dominance efforts in coordination with the United States Air Force and Navy and explored potential technology developmental areas to ensure the air superiority of the United States in the future. The study considered roles of manned and unmanned platforms; the relative performance of alternative integrated systems concepts that combine various mixes of capabilities networked together; and the cost effectiveness of alternative balances of platforms and systems that provide surveillance, command and control, electronic warfare, and weapons functions. Innovative concepts for platform, propulsion, sensors, weapons integration, avionics, and active and passive survivability features were explored as part of the concept definition effort. This effort explored the expanded development and use of automated and advanced aerospace engineering design tools, modeling, and simulation in areas that can increase the likelihood of producing more capable products with improved efficiency. Following the initial multi-agency study, DARPA presented technical challenges to industry to allow them to explore and present potential solutions as part of the technical feasibility and system integration studies. Enabling technologies are advanced networking capabilities, reliable navigation, passive and active defense, electronic	5.000	-	-

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
attack, area denial, advanced sensors, and cyber technologies. After the study, it is envisioned that high-potential prototype programs will emerge to develop technologies for future air dominance. Early planning for future technologies will also help to define the funding baselines for DoD research and development and acquisition programs. ***FY 2014 Accomplishments:*** - Conducted technology feasibility and system integration studies of identified high value technologies. - Conducted Technical Interchange Meeting (TIM) to coordinate between development efforts. - Briefed senior leadership on results of technology development efforts, with high-potential prototype programs recommendations.			
Accomplishments/Planned Programs Subtotals	146.789	129.723	185.043

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

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

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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	127.948	179.883	126.692	-	126.692	130.091	188.935	205.471	191.226	-	-
SPC-01: *SPACE PROGRAMS AND TECHNOLOGY*	-	127.948	179.883	126.692	-	126.692	130.091	188.935	205.471	191.226	-	-

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 propulsion/propellants, unique manufacturing or assembly processes; precision control of multi-payload systems, and payload isolation and pointing systems.

B. Program Change Summary ($ in Millions)

	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	142.546	179.883	169.626	-	169.626
Current President's Budget	127.948	179.883	126.692	-	126.692
Total Adjustments	-14.598	-	-42.934	-	-42.934
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-9.611	-			
• SBIR/STTR Transfer	-4.987	-			
• TotalOtherAdjustments	-	-	-42.934	-	-42.934

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Change Summary Explanation

FY 2014: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2016: Decrease reflects drawdown of the Airborne Launch Assist Space Access (ALASA) and Space Domain Awareness (SDA) programs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Airborne Launch Assist Space Access (ALASA)	30.448	60.000	29.000

Description: The ALASA program has four major goals. The first of these is to make access to space more affordable by reducing the cost per launch to under one million dollars per flight. ALASA accomplishes this by using a simple design, with minimal infrastructure, touch labor, and range support. Secondly, 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. Finally, ALASA will demonstrate the ability to move its operations from one airfield to another in twelve hours to show resilience in the presence of the initial operating airfield being unavailable, even from factors as relatively innocuous as the weather. The system uses the Air Force's F-15 fleet, getting as much energy as possible from the reusable part of the system, but without costly modifications to the aircraft. Challenges include, but are not limited to: in-air separation of aircraft and orbit-insertion launch stages, 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 partner is the Air Force.

FY 2014 Accomplishments:
- Conducted trade studies of additional enabling technology to include propellants, manufacturing, mission planning and range support software, and tracking and flight termination software.
- Began detailed design of selected ALASA demonstration system.
- Developed detailed planning and operations concepts for testing the ALASA demonstration system.
- Performed propulsion and system risk reduction testing.
- Completed Preliminary Design Review.

FY 2015 Plans:
- Conduct propellant handling and characterization testing and propulsion system hot-fire testing.
- Conduct Critical Design Review.
- Conduct captive carry and aircraft compatibility flight tests.
- Conduct analysis of launch performance metrics and identify opportunities for system design and integration optimization.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Continue transition coordination. ***FY 2016 Plans:*** - Initiate demonstration of ALASA vehicle launches including launch readiness reviews. - Conduct three initial launches with engineering payloads to qualify space based telemetry system, automatic flight termination system, and payload environment measurements. - Conduct nine additional launches to demonstrate the advantages of tailored, dedicated launch capability. - Coordinate transition of ALASA system to the Air Force. - Transition space based telemetry and automatic flight termination technology to the launch community.			
Title: Experimental Spaceplane One (XS-1) ***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) Mach 10+ flight, and 3) 10X lower cost space access for cargoes 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 2014 Accomplishments:*** - Developed a conceptual design for the XS-1 demonstration system including detailed structural analysis and mass properties. - Performed system level trade studies to identify alternative configurations and defined the tradespace for XS-1. ***FY 2015 Plans:*** - Conduct risk reduction studies for propulsion, thermal protection systems, guidance/avionics, composite materials, propellant tanks and space based communications. - Conduct a mid-phase Conceptual Design and Systems Requirements Review. - Conduct component, wind tunnel, and subsystem testing and verification. - Continue to develop detailed XS-1 designs including mass properties, configuration, aerodynamic, trajectory and thermal protection data. - Conduct a Preliminary Design Review and select design for technology risk reduction. ***FY 2016 Plans:*** - Develop detailed finite element model structural and thermal analysis for the XS-1 design.	10.000	27.000	30.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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 2014	FY 2015	FY 2016
- Perform aerodynamic Computational Fluid Dynamics analysis and wind tunnel testing for the XS-1 design. - Complete the system and subsystem designs, mass properties and configuration required to support the Critical Design Review. - Develop the concept of operation including the maintenance concept, performance, trajectories and design reference missions. - Coordinate with the Federal Aviation Administration, federal ranges and spaceports to accomplish preliminary flight test planning. - Begin developing a plan to accomplish ground operations, facility modifications and flight demonstration.			
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 servicing program will build upon these legacy technologies, tackling the more complex GEO environment and expanding beyond pure traditional servicing functions. The program seeks to validate robotics operations in GEO suitable for a variety of potential servicing tasks, in full collaboration and cooperation with existing satellite owners. The program will examine utilization of a new commercial ride-along capability to GEO called Payload Orbital Delivery (POD) to support hardware delivery for upgrading, repairing, assembling, and reconfiguring satellites. The program will include an early LEO flight experiment focused on satlets as a path of risk reduction for modular assembly on orbit. Key challenges include robotic tool/end effector requirements, efficient orbital maneuvering of a servicing vehicle, robotic arm systems, and integration and efficient and low cost transportation of robotic tools. The anticipated transition partners are the Air Force and the commercial spacecraft servicing providers. Beginning in FY 2015, the GEO robotics portion of this effort will be funded under the Robotic Servicing of Geostationary Satellites program within this Project. ***FY 2014 Accomplishments:*** - Delivered prototypes of hardware and software for various servicing tasks to robotic testbed for validation and integration with tools. - Completed mission validation testing inside a six degree of freedom testbed. - Conducted critical design review for LEO satlet experiment and demonstrations. ***FY 2015 Plans:*** - Conduct pre-ship review for early LEO satlet experiment equipment and deliver to launch integrator. - Complete delta critical design of satlets per lessons learned from LEO experiment.	57.500	55.000	19.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Complete delta critical design of PODs for first GEO flight. ***FY 2016 Plans:*** - Launch early LEO satlet experiment and conduct experiment operations. - Launch GEO POD flight 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 geostationary 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 in this Project, will establish robotics operations in GEO suitable for a variety of potential servicing tasks, in full collaboration and cooperation with existing satellite owners. The program will establish the ability to assist with mechanical malfunctions such as solar array deployment; provide assistive thrust to increase the flexibility of fleets of operational satellites; and use camera systems to perform very detailed inspections to help troubleshoot satellite problems and increase transparency of GEO operations. Key challenges include; developing automated robot reflexes for safety of operations, robotic tools, efficient orbital maneuvering of the servicing vehicle, robotic arm systems, and mission simulation and validation. The anticipated transition will be through a commercial spacecraft operator who will provide services to both commercial and military satellites on a fee-for-service basis. ***FY 2015 Plans:*** - Complete critical design of robotic servicing system including robotic arms and tool docking system. - Validate specific servicing mission types that maximize value for commercial and DoD satellite operators. - Begin fabrication of primary and secondary robotic hardware and software. - Develop detailed requirements developed from mission description and commercial operator needs. ***FY 2016 Plans:*** - Establish partnership with satellite bus provider. - Develop interfaces between servicer satellite and government-provided robotic payload. - Develop comprehensive test plan for robotics and for integrated system. - Begin fabrication of servicer satellite with commercial partner.	-	4.000	10.000
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	8.000	9.000	9.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 Australia will investigate telescope performance and observe objects and orbits not visible from the current site in New Mexico. 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 2014 Accomplishments:*** - Continued evaluation of operational strategies, technology studies, and hardware demonstrations in order to optimize SST performance at Australia site. - Continued research at Atom site into technical challenges facing the system after relocation. - Completed MOU with Australia. - Refined SST relocation plan, jointly with the Australian Department of Defense partners. ***FY 2015 Plans:*** - Continue to refine SST relocation plan jointly with Air Force Space Command (AFSPC) and the Australian Department of Defense partners. - Conduct SST sustainment studies. ***FY 2016 Plans:*** - Recoat mirrors at Kitt Peak Arizona. - Ship SST Telescope Mount Gimbal (TMG) to Australian site. - Ship SST optics to Australian site.			
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	18.000	19.883	5.692

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
deep space orbits, where a majority of DoD spacecraft are located. Additionally, servicing missions to geosynchronous (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. The SDA program will develop a space management system that allows cognitive reasoning and decision support to execute space operations with current and proposed assets within real and synthetic environments. 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, 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 correlate a wide range of operational support and space system user data to rapidly identify threat activities, propose mitigating countermeasures, and verify the effectiveness of selected responses. Critical technologies include accessing disparate sources of relevant data in a common scalable database, model-based situational awareness, and candidate response generation and evaluation. Particular emphasis will be placed on the ability to continuously adapt to changes in defended system components and usage patterns as well as validation of system integrity. 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. Also funded within this program is the Galileo effort, which will develop technology to image a Geosynchronous Earth Orbit (GEO) satellite from the ground. Galileo will utilize fixed mobile telescopes, each with adaptive optics and a guide star, to create multiple baselines that can be used to reconstruct the image through an inverse Fourier transform. The potential transition customer is the Air Force. ***FY 2014 Accomplishments:*** - Initiated the StellarView network of academic astronomy data providers. - Initiated novel dynamic database to collect networked source information for validation. - Demonstrated preliminary capability of the Allen Telescope Array to passively detect and track satellites. - Commenced astrometric data processing and validation efforts. - Commenced SpaceView Phase 2 to demonstrate additional amateur nodes including Australia locations. - Completed Galileo risk reduction experiments in ground-based sparse aperture imaging technologies.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Conducted a survey of operational management systems for Real-Time Space Domain Awareness. ***FY 2015 Plans:*** - Expand the SpaceView amateur network to additional nodes including Australia locations. - Incorporate international data sources into SDA database. - 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. - Initiate data ingest from the StellarView network of academic astronomy data providers. - Commence Phase 1 of an un-cued low inclined LEO object detection capability. - Perform database verification on collected data; demonstrate metric and radiometric accuracy. - Study the application of coherent and quantum detectors to Space Domain Awareness challenges of object detection and imaging. - Initiate Real-Time Space Domain Awareness design development. ***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.			
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 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 Plans:***	-	5.000	6.000

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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
- Investigate essential technologies to facilitate self-organizing robotic construction in space. - Conduct ground-based risk reduction experiments for critical path technologies. - Develop improved piezopolymer controlled deformable mirrors which can be deployed in a self-assembling orbital optical aperture. - Develop 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. - Perform risk reduction activities on strain-deployed, piezo-aligned, lightweight sparse aperture optical concept to support orbital Intelligence, Surveillance, and Reconnaissance (ISR). ***FY 2016 Plans:*** - Demonstrate 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. - Complete System Requirements Review (SRR) and Preliminary Design for a system of SmallSat modules and mission specific attachments traceable to space operations.			
Title: Advanced Space Propulsion Technologies ***Description:*** The advanced propulsion technologies program will examine and evaluate space propulsion technologies that will enable order of magnitude improvement in existing systems as well as new missions/capabilities in space. Technologies to be explored include new materials and new propellants, novel thruster and engine designs, and methods/processes to increase efficiency at lower cost. The program will conduct proof of concept risk reduction activities leading to potential on orbit demonstration of the most promising technologies. ***FY 2016 Plans:*** - Initiate new studies of novel technologies. - Conduct risk reduction tests of candidate technologies.	-	-	2.000
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	-	-	6.000

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C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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.			
Title: Hallmark ***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 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:*** - 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.	-	-	10.000
Title: System F6 ***Description:*** The System F6 program sought to demonstrate the feasibility and benefits of satellite architecture technologies which facilitate a fractionated architecture wherein the functionality of a traditional "monolithic" spacecraft is replaced by a cluster of wirelessly-interconnected spacecraft modules. Each such "fractionated" module could contribute a unique capability, for example, computation and data handling, communications relay, guidance and navigation, payload sensing, or it would replicate the capability of another module. The cluster would deliver a comparable mission capability to a monolithic spacecraft. The fractionated modules would fly in a loose, proximate cluster orbit capable of semi-autonomous reconfiguration or a rapid defensive scatter/re-gather maneuver. The program developed key technologies to facilitate fractionated and disaggregated architectures. The F6 Technology Package (F6TP), a suite of technologies, components, and algorithms that enables semi-autonomous	3.000	-	-

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C. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
multi-body cluster flight and secure, distributed, real-time sharing of various spacecraft resources at the cluster level was also developed. ***FY 2014 Accomplishments:*** - Completed F6TP engineering development units. - Completed cluster flight application software development and testing. - Completed a fully-functional, documented, value-centric architecture and design tool for adaptable space systems. - Completed flight unit of the persistent broadband terrestrial connectivity terminal for Low Earth Orbit (LEO) fractionated clusters.			
Title: SeeMe ***Description:*** The SeeMe program explored methods to provide near-real-time (for example, no older than ~90 minutes) images and other data directly to individual users' handheld devices from space using a very low cost constellation of inexpensive, disposable small satellites routinely and inexpensively put in orbit through low-cost (for example, horizontal) launches. SeeMe sought to radically shorten the entire cycle: ground development time, launch cadence, and on-orbit request-to-image-delivery time through new satellite manufacturing techniques, advanced low-cost aperture technologies, leveraging alternative launch concepts, and a novel direct-to-user command and data exfiltration architecture. ***FY 2014 Accomplishments:*** - Completed preliminary design of system hardware and software for the satellites. - Completed prototype hardware field demonstrations (through balloon testing) to support radio uplink and downlink direct to user handhelds. - Completed technology prototype units, performed functional and environmental tests, and demonstrated operation. - Developed the first space factory to showcase high volume low cost satellite manufacturing capability.	1.000	-	-
Accomplishments/Planned Programs Subtotals	127.948	179.883	126.692

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

F. Performance Metrics

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

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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	92.001	92.246	79.021	-	79.021	87.381	115.033	148.689	169.859	-	-
MT-12: *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	-	32.632	14.264	-	-	-	-	-	-	-	-	-
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	59.369	77.982	79.021	-	79.021	87.381	115.033	148.689	169.859	-	-

A. Mission Description and Budget Item Justification

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

The MicroElectroMechanical Systems (MEMS) and Integrated Microsystems Technology project 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. MEMS applies the advantages of miniaturization, multiple components and integrated microelectronics to the design and construction of integrated electromechanical and electro-chemical-mechanical systems to address 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. The project will also address thermal management, navigation and positioning technology challenges.

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.

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B. Program Change Summary ($ in Millions)	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	107.080	92.246	83.198	-	83.198
Current President's Budget	92.001	92.246	79.021	-	79.021
Total Adjustments	-15.079	-	-4.177	-	-4.177
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-11.913	-			
• SBIR/STTR Transfer	-3.166	-			
• TotalOtherAdjustments	-	-	-4.177	-	-4.177

Change Summary Explanation

FY 2014: Decrease reflects below threshold and omnibus reprogrammings and the SBIR/STTR transfer.

FY 2016: Decrease reflects completion of the MEMS and Integrated Microsystems Technology Project (MT-12).

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
MT-12: *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	-	32.632	14.264	-	-	-	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

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 current focus in micro technologies is to improve navigation, position and timing capabilities for uncompromised navigation and positioning in today's dynamic military field of operations.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 the development of new microfabrication processes and novel material systems for fundamentally different sensing modalities, understanding of the 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.	28.259	14.264	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
FY 2014 Accomplishments: - Demonstrated basic functionality of miniature atomic physics-based inertial sensors. - Demonstrated functionality of MEMS gyro and co-fabricated calibration stage. - Demonstrated integration of atomic interferometry inertial sensor with high-bandwidth co-sensor. - Demonstrated miniaturized trapped ion clock, with roadmap to self-contained, portable operation. - Demonstrated electronic gyroscope self-calibration with long-term scale factor and bias of <10 ppm of full range. - Demonstrated personal navigation for 4-hour long test with tight integration of MEMS and foot-to-foot ranging. ***FY 2015 Plans:*** - Demonstrate a miniature, self-contained atomic gyroscope with Angle Random Walk (ARW) < 0.05 degrees/sqrt(hr) and bias stability < 0.01 degrees/hr. - Demonstrate self-calibrating MEMS gyroscope with long-term scale factor and bias of <1 ppm of full range.			
Title: Blast Exposure Accelerated Sensor Transfer (BEAST) ***Description:*** The Blast Exposure Accelerated Sensor Transition (BEAST) program built on progress made through the Blast Gauge program and enabled a better understanding of blast-related injuries such as Traumatic Brain Injury (TBI) and Post-Traumatic Stress Disorder (PTSD). During a blast event, the Blast Gauge device captures environmental data and available operational information in order to develop a 3D recreation of the event. The BEAST program provided additional tools for the military community, conducted cognitive testing in high risk service members, and expanded the current knowledge base of the impact of blast exposure by correlating physiological and behavioral changes with direct measures of blast-exposure. Ultimately, these results contributed to the TBI and PTSD knowledge base for improved treatment, developed enhanced understanding of blast events to mitigate exposure and improved training procedures, and aided in completing the transition of the Blast Gauge device to military service sustainment. ***FY 2014 Accomplishments:*** - Supported medical studies using Blast Gauge devices. - Completed development of a web-based tool to store, organize, analyze, and visualize Blast Gauge recordings. - Issued 5th generation Blast Gauge devices to groups of Service members. - Concluded verification and validation blast testing event with Army Testing Center at Aberdeen Proving Grounds. - Finalized approvals to commence clinical studies on physiological and behavioral measures correlated to blast exposure. - Established data collection plan for cognitive testing in clinical participants.	4.373	-	-
Accomplishments/Planned Programs Subtotals	32.632	14.264	-

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

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 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	59.369	77.982	79.021	-	79.021	87.381	115.033	148.689	169.859	-	-

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 2014	FY 2015	FY 2016
Title: Endurance	17.859	37.669	23.473
Description: The Endurance program will develop technology for pod-mounted lasers to protect a variety of airborne platforms from emerging and legacy electro-optical IR guided surface-to-air missiles. The focus of the Endurance effort will be to develop and test ancillary subsystems, such as a command subsystem, a threat missile warning subsystem, a mechanical support framework, subsystem interfaces, and the design, integration, and testing of a form/fit/function brass-board 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 2014 Accomplishments:*** - Developed critical design of ancillary subsystems (power supply, thermal management, processing and control, mechanical support framework). - Developed preliminary design for subsystem integration including optical and electrical interconnections and their layouts. ***FY 2015 Plans:*** - Acquire threat devices and/or surrogates in preparation for live fire testing. - Complete the critical design for subsystem integration. - Integrate, assemble and bench-test the brassboard system. ***FY 2016 Plans:*** - Test the brassboard laser weapon system at an outdoor test range against a representative set of dynamic-threat targets. - Assess brassboard system performance in live-fire testing.			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Develop a preliminary engineering design for a flight-prototype of a pod-mounted laser weapon system.			
Title: Diverse & Accessible Heterogeneous Integration (DAHI)	13.910	20.300	12.754

Description: Prior DARPA efforts have demonstrated the ability to monolithically integrate different semiconductor types to achieve near-ideal "mix-and-match" capability for DoD circuit designers. Specifically, one such program was the Compound Semiconductor Materials On Silicon (COSMOS) program, in which transistors of Indium Phosphide (InP) could 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, Gallium Nitride (GaN), InP, Gallium Arsenide, 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" (SoC) and allow dramatic size, weight and volume reductions for a wide array of system applications.

This program has basic research efforts funded in PE 0601101E, Project ES-01 and 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.

FY 2014 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 Transistor (HBTs), GaN High-electron-mobility transistor (HEMTs), and high-Q passive devices).
- Developed three-technology chiplet-based heterogeneous integration process for use in initial heterogeneous integration multi-project wafer foundry fabrication run.
- Developed process for integration of third-party device technologies in heterogeneous integration foundry.
- Established heterogeneous integration design/simulation tool flows necessary to realize the full potential of heterogeneous microsystems integration.
- Developed thermal simulation tools and process design kit for heterogeneous integration process.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Demonstrated capability for supporting multi-project wafer runs using the heterogeneous foundry service under development. - Demonstrated design support capabilities and mask aggregation for initial heterogeneous integration foundry run. - Accelerated development of circuit design techniques and methodologies that enable revolutionary heterogeneously integrated circuit architectures. - Developed example circuits and circuit design block library for use by circuit design teams in initial heterogeneous integration foundry run. ***FY 2015 Plans:*** - Continue to develop 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). - Continue to demonstrate capability for supporting multi-project wafer runs using the heterogeneous foundry service under development. ***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.			
Title: FLASH - Scaling Fiber Arrays at Near Perfect Beam Quality ***Description:*** The goal of the FLASH program is to demonstrate a transportable, packaged laser system whose output is derived from 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 size, weight, and power (SWaP) will be consistent with weight and volume densities needed to support the integration of laser weapons on a broad range of Military platforms. To accomplish these ends, 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 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 laser system. ***FY 2014 Accomplishments:*** - Demonstrated a benchtop array of 1.3 kW fiber-lasers combined to produce a >30 kW near-diffraction-limited output at >25% electrical-to-optical efficiency.	11.600	18.013	14.100

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Estimated the capability of a 21-element optical-phased array system to compensate for atmospheric turbulence under various atmospheric conditions. - Demonstrated target-in-the-loop phase-locking on a stationary target at a 7 km distance. ***FY 2015 Plans:*** - Develop and test 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. - Develop a preliminary design for a >30 kW, transportable, packaged laser system including fiber lasers, thermal management, power systems, and beam combination. ***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.			
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 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 2014 Accomplishments:*** - Defined system architecture and flow-down metrics for individual components. - Designed and fabricated a novel, single channel optical receiver chip capable of receiving electrical pulses that are < 2 ps wide. - Designed remote sampling head and sourced components to incorporate electronic RF frontend, electro-optic modulator, and 4 GHz-wide filter. ***FY 2015 Plans:***	2.000	2.000	2.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Design, fabricate and test the second generation optical receiver chip with 8 channels and optimized optical response to minimize the parasitic capacitance of the circuit. - Complete system engineering of field programmable gate array capable of continuous streaming of digital data. - Demonstrate direct sampling of a 2 GHz-wide bandwidth signal at 9 effective bits of fidelity. ***FY 2016 Plans:*** - Demonstrate direct sampling of a 4 GHz-wide bandwidth signal at 10 effective bits of fidelity.			
Title: Photonic Radio ***Description:*** The rapid pace of wireless technology development has created a commercial technology base with accessible components that span the radio spectrum up to 100 GHz. When faced with agile or unknown threats across decades of bandwidth, conventional radio frequency (RF) systems perform poorly. Massively channelized receivers spanning just tens of GHz also have unacceptable size and power envelopes for very large defense platforms. Recent developments in integrated photonics have demonstrated the potential to channelize, filter and down-convert RF signals in the photonic domain with significantly improved performance and greatly reduced size. The Photonic Radio program will build on this foundation to deliver a chip-scale photonic channelized receiver spanning 20 to 50 GHz in 200 MHz-wide channels. The program will design and build a complete and compact solution with intimate integration of electronics with high performance photonic devices, such as very high Q filters and on-chip high-power lasers. The program will also package the prototype system and conduct field tests for insertion into advanced weapons systems. ***FY 2016 Plans:*** - Design and simulate the complete channelized receiver and generate flow down specifications to component technologies. - Fabricate and test integrated photonic down-converter and high-Q filters with more than 55 decibels of dynamic range.	-	-	9.890
Title: Fast and Big Mixed-Signal Designs (FAB) ***Description:*** 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. This program 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 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	-	-	7.200

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
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, FAB 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.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM) ***Description:*** The Precise Robust Inertial Guidance for Munitions (PRIGM) program will develop low-Cost, Size, Weight, and Power (CSWaP) inertial sensor technology for GPS-free munitions guidance. 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. 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 PRIGM program will advance the technology readiness level (TRL) of state-of-the-art MEMS inertial sensors from TRL-3 to TRL-6. 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 to TRL-7. This program has applied research efforts funded in PE 0602716E, Project ELT-01.	-	-	6.286

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
FY 2016 Plans: - Initiate efforts to demonstrate MEMS inertial sensors that meet all NGIMU performance requirements with relaxed environmental requirements - Design, fabricate, and characterize gyroscopes with Angle Random Walk (ARW) of 0.0035 deg/rt(hour), turn-on-to-turn-on bias repeatability of 0.001 deg/hr, in-run bias stability of 0.001 deg/hr, and scale factor repeatability of 5 ppm. - Design, fabricate, and characterize accelerometers with Velocity Random Walk (VRW) of 1 mm/sec/rt(hour), turn-on-to-turn-on bias repeatability of 25 micro-g, in-run bias stability of 10 micro-g, and scale factor repeatability of 100 ppm.			
Title: Microwaves and Magnetics (M&M) ***Description:*** Passive magnetic components such as frequency selective limiters (FSL), isolators, circulators, phase shifters and filters are integral to numerous military electronic systems in applications including radar, imaging, communications, and electronic warfare. However, the rate of development and level of integration in microwave and mm-wave magnetic components have severely lagged the corresponding advancements and monolithic integration of semiconductor, microelectromechanical systems (MEMS), and optical active devices. In some cases the magnetic technologies have changed little in the past 20 to 30 years. The Microwaves and Magnetics program will leverage advanced magnetic components leading to disruptive improvements in system performance and novel functionality. A particularly attractive magnetic component for front-end receivers is FSL. An FSL is a device that automatically attenuates high power signals above a certain threshold while allowing low power signals at different frequencies to pass. Use of FSLs will enable receivers to operate in the presence of strong interferers providing wideband protection, enable operation in congested RF environments, and increase effective dynamic range. Corresponding advances in other magnetic components and technologies will dramatically improve the performance, and increase the integration level of transmitters and receivers for Department of Defense (DoD) applications. This program has applied research efforts funded in PE 06020716E, Project ELT-01. ***FY 2016 Plans:*** - Leverage advances in magnetic materials and microwave design and modeling techniques to initiate the design of a FSL with low insertion loss, wide bandwidth, improved transient response, and high power handling capability. - Explore potential opportunities for system integration and develop a test plan that will provide supporting FSL performance data.	-	-	3.318
Title: Low Cost Thermal Imager - Manufacturing (LCTI-M) ***Description:*** The Low Cost Thermal Imager - Manufacturing (LCTI-M) effort built upon previous manufacturing and imaging work and developed a pocket-sized and smartphone-integrated, manufacturable, and practical thermal imager at a price point that allows it to be provided to large numbers of warfighters. Availability of very low cost and small form-factor infrared (IR) cameras facilitates new techniques and applications that could provide the decisive edge needed in modern battlefields. These cameras	14.000	-	-

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
allow a soldier to have practical thermal imaging capability for locating warm objects (e.g., enemy combatants) in darkness. The small size, weight and power (SWaP) thermal camera can be integrated with a handheld device such as a cell phone with network capability for tactical intelligence, surveillance and reconnaissance. The imager chips were fully integrated with a low-cost processor and optics. The camera has wireless connectivity to integrate video display with cell phones or PDAs. U.S. Army PEO Soldier Sensors and Lasers (SSL), PM Optics USMC, USSOCOM and industry are the transition partners. ***FY 2014 Accomplishments:*** - Completed low-cost wafer-scale optics for LCTI-M camera. - Demonstrated small-form-factor camera integration employing 3-D assembly techniques. - Delivered interim prototype cameras for testing. - Delivered final 640x480 LCTI-M cameras with test results and 1280X1024 camera engines.			
Accomplishments/Planned Programs Subtotals	59.369	77.982	79.021

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	229.510	239.265	201.335	-	201.335	122.646	147.512	132.324	133.683	-	-
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	141.023	135.561	115.265	-	115.265	110.646	135.512	124.324	133.683	-	-
CCC-04: *SECURE INFORMATION AND NETWORK SYSTEMS*	-	11.740	1.706	-	-	-	-	-	-	-	-	-
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	76.747	101.998	86.070	-	86.070	12.000	12.000	8.000	-	-	-

A. Mission Description and Budget Item Justification

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

The 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 will develop and demonstrate 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 will develop, integrate, and test technologies for re-using software components.

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
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*

B. Program Change Summary ($ in Millions)	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	239.078	243.265	227.402	-	227.402
Current President's Budget	229.510	239.265	201.335	-	201.335
Total Adjustments	-9.568	-4.000	-26.067	-	-26.067
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-4.000			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-2.500	-			
• SBIR/STTR Transfer	-7.068	-			
• TotalOtherAdjustments	-	-	-26.067	-	-26.067

Change Summary Explanation

FY 2014: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2015: Decrease reflects congressional reduction.
FY 2016: Decrease reflects completion of the Computational Leverage Against Surveillance Systems (CLASS), Fixed Wireless at a Distance, and Mobile Hotspots programs.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	141.023	135.561	115.265	-	115.265	110.646	135.512	124.324	133.683	-	-

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 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: 100 Gb/s RF Backbone	10.000	13.770	21.750
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 2014 Accomplishments:*** - Developed millimeter-wave waveforms with higher modulation constellation to achieve high spectral efficiencies. - Began developing approaches to achieving power transmission efficiency improvements at mmW frequencies.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Began developing low noise-figure receiver technologies for mmW frequencies. - Began developing and testing candidate architectures, hardware, and algorithms for spatial multiplexing to achieve high spectral efficiencies. ***FY 2015 Plans:*** - Build and evaluate modulators capable of generating high-order waveforms and demodulators capable of digitizing the high-order waveforms. - Evaluate high-order modulation approaches at mmW frequencies in field demonstrations to tactically relevant distances. - Evaluate the hardware and software capable of spatially multiplexing and de-multiplexing multiple mmW signals. - Evaluate mmW spatial multiplexing approaches to distances at or beyond the Rayleigh Range. ***FY 2016 Plans:*** - Begin design and development of integrated prototype system that includes higher-order modulation and spatial multiplexing. - Continue to reduce the size, weight, and power of the system components to metrics consistent with high altitude, long endurance aerial platforms. - 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.			
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 2014 Accomplishments:*** - Developed techniques to characterize reliability of information in networks with misbehaving devices and evaluate performance through simulation.	12.000	18.880	16.550

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Developed approaches using the control functions of wireless networks using reliability values to create innately resilient control systems. - Determined system-level performance goals for subsequent phase of the program. - Began integration of most promising technology components for reliability estimation and robust network control into laboratory prototypes of robust wireless networks. ***FY 2015 Plans:*** - Complete integration of candidate algorithms and protocols for protecting networks from, and detecting and reacting to, misinformation attacks in laboratory-based prototype systems. - Test resilience of prototype capabilities in a laboratory environment. - Refine protection mechanisms based on test findings and begin development of systems for field demonstrations. - Quantify the performance impact of network misconfiguration in simulations of networks in contested environments. ***FY 2016 Plans:*** - 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. - Integrate with military tactical radios and quantify the performance impact through experiments.			
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 2014 Accomplishments:*** - Developed concepts and management policies for enabling radars and communications networks to share spectrum spatially and temporally.	8.400	23.899	18.840

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Developed models and simulation capability for research on spectrum sharing between radar and communications systems. - Assessed the limits on achievable spectral reuse between radar and communications in order to evaluate sharing concepts and implementations. - Assessed threats to military systems created by sharing spectrum information with non-military users. ***FY 2015 Plans:*** - Model and assess multiple mechanisms for spatial and temporal spectrum sharing between radars and communications networks. - Develop and assess a baseline set of strategies to defend military systems against threats created by sharing spectrum information between military radars and commercial communications systems. - Develop concepts for a control system to manage mechanisms for spectrum sharing between radars and communication systems. - Demonstrate technologies for signal separation between radar and communications systems operating at the same time, place, and frequency. - Develop 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. - Demonstrate spectrum sharing among conforming radar and communications systems that incorporates multiple sharing mechanisms. - Model and assess performance of jointly designed military radar and military communications systems operating in a shared spectrum allocation in electronic countermeasure operating environments.			
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 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	15.577	17.762	17.125

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016

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 2014 Accomplishments:
- Developed and deployed prototype networks employing multiple types of RF devices of different types for experimentation with the RF mapping technology.
- Demonstrated RF mapping capability to characterize RF signals in tactically relevant VHF and UHF frequency bands, using a limited number of distributed devices while minimizing communications requirements between devices.
- Determined the performance improvement for signal detection and identification of RF mapping systems over tactically relevant collection times.
- Improved RF collection capabilities to cover low-rate tactical networks and limited device availability in tactical environments.
- Established baseline capability for defending against hostile use of the RF spectrum.

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

FY 2016 Plans:
- Conduct RF Mapping experiments with Services during field exercises.
- Develop a management console enabling mission planners to configure the RF mapping system.
- Develop a baseline user interface for presenting RF mapping information to tactical unit leaders.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Develop software for interconnecting the RF mapping capability with other tactical EW systems enabling cueing and results sharing. - Develop software for storing RF maps and querying the stored data.			
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, working to expand Low Probability of Detection/Anti-Jam (LPD)/(AJ) technologies, seeks 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 are in development: 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 is to make modular communications technology that is inexpensive to incorporate in existing and emerging radio systems (<$100 incremental cost) but pushes adversaries to need more than 1,000x our processing power - supercomputer-level processing power. Another track of the program will extend the CLASS technology to provide LPD communications. These techniques will drastically reduce the detectability of communications signals beyond current capabilities. Scalable performance will allow LPD techniques to better trade information rate for communications capacity. Technologies from this program are planned to transition to the Services. ***FY 2014 Accomplishments:*** - Developed operational concepts for distributed airborne operations. - Conducted RF transceiver studies for airborne operations. - Finalized design of CLASS RF and modem integrated circuits; released to foundry for fabrication. - Integrated application driver software for CLASS technology in preparation for Application Specific Integrated Circuits (ASIC) testing. - Produced modular CLASS products and developed board for ASIC testing and a radio product module. - Leveraged advancements towards an alternative development environment for communications systems that takes advantage of commercial smartphone development environment methodology. - Developed an alternative generalized reference architecture that supports communications system integration specifically, and that supports future revisions for other electronic systems anticipated in airborne force projection systems. - Investigated candidate satellite constellation configurations to quantify the trade-off between space segment cost and system coverage and capacity.	28.325	24.600	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Investigated techniques to collaborate among distributed transmitters and receivers for the geometries of beyond line-of-sight solutions (such as airborne and/or space layers), and quantify expected performance relative to predicted system threats. - Investigated applying CLASS receiver beamforming techniques for blind interference cancellation to the Link 16 waveform. - Conducted multi-kilometer demonstration of coherent distributed communications. ***FY 2015 Plans:*** - Develop concepts for integrating CLASS technologies with aircraft antennas and communications equipment. - Measure CLASS modem performance processing power, power consumption, and radio waveform interoperability. - Integrate CLASS modular technology with host processor. - Demonstrate CLASS communication capability with and without interference against Army threat intercept surrogates. - Measure CLASS modem transmit power reduction as number of cooperative transmitters is increased from 1 to 8. - Conduct field tests of integrated CLASS system. - Analyze field test data and compare achieved performance to program metrics.			
Title: Communication in Contested Environments ***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 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 Networks technologies efforts, the Communication in Contested Environments (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 2014 Accomplishments:***	4.033	18.000	18.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Created initial version of a development environment for military communications applications and waveforms similar to the development environments used in the commercial smartphone market. - Developed an initial reference architecture to support interoperable communications and heterogeneous networking. ***FY 2015 Plans:*** - Build a communications reference hardware system to support L-band and microwave communications. - Breakdown waveform implementations into re-usable processing elements and compile representative waveforms for the reference hardware. - Build infrastructure networking automation layer for link establishment, maintenance, and service prioritization. - Test infrastructure networking code on the reference system and evaluate pervasive networking performance. ***FY 2016 Plans:*** - Complete development of advanced network patterns. - 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 a C2E reference design on a small form factor UAV. - Finalize development of the C2E waveforms and demonstrate performance through laboratory testing.			
Title: Scalable Optical Nodes for Networked Edge Traversal (SONNET) ***Description:*** 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 demand on the processors is low, resulting in extremely low compute efficiency. Computationally, graph analysis is characterized by many short, random accesses to memory which is inefficient on current systems, which are optimized for regular predictable access. The SONNET program will build a silicon photonics-based graph processor that will perform graph analysis on terabytes (TBs) of data with performance comparable to peta-scale supercomputers in a significantly smaller size, weight and power (SWaP) envelope. SONNET will optimize the design of the graph processor by co-designing processor and photonic hardware, and the computer and network architectures to exploit the high bandwidth provided by silicon photonics. SONNET will demonstrate a scalable, power efficient prototype of such a graph processor and quantify performance for DoD-relevant applications. The performance, efficiency, and size will be transformational for big data analytics and enable real-time analysis on dynamic graphs in the fields of cyber security, threat detection, and numerous others. This program will explore the efficient processing of local information using stacked memory and integrated circuits specially made for specific tasks, as well as the efficient transfer of data between local information processors.	-	-	8.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
The SONNET program will optimize silicon photonic links and improve their power efficiency while also developing packaging techniques for high bandwidth silicon photonic transceivers. SONNET will integrate high capacity memory cards with photonic transceivers to enable high bandwidth access to high capacity memory. The program will build a four node prototype system with a silicon photonic switch connecting the nodes. The program will demonstrate the scalability of the prototype to petascale computational capability. This will also explore the use of processing very close to a stacked memory to investigate the benefits of local processing within the islands connected by the photonic links. This program has applied research efforts funded in PE 0602303E, Project IT-02. Technologies developed under this program will transition to the Services. ***FY 2016 Plans:*** - Demonstrate fully integrated, high efficiency, multi-channel photonic link in a silicon platform, scalable to the bandwidth requirements of the prototype. - Identify gaps in optical packaging technology and design solutions to enable a fully packaged prototype.			
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 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. ***FY 2016 Plans:***	-	-	7.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- 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. - Develop and demonstrate the 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.			
Title: Self-Optimizing Networks ***Description:*** Wireless networks have evolved into complex systems having many configurable parameters/features, including link data rates, power settings, inter-network gateways, and security associations. The optimal settings for these features vary greatly depending on the mission for which the network is deployed and the environment in which it is operating. Currently, the majority of these features are optimized off-line for specific scenarios and assumptions and are pre-set before use in a mission. There is no capability for the settings to adapt if the actual mission or environment differs from the original assumptions used to configure the network. The problem is exacerbated in scenarios in which intelligent adversaries can affect the topology and operation of the network unpredictably and on short timescales. Furthermore, future operations will include multiple, different radios interconnected on the same platform, which requires adaptation of the interaction between different networks. Building upon concepts explored under the Wireless Network Defense program, which is budgeted in this PE/Project, the Self-Optimizing Networks program will develop new approaches to configuring and controlling networks and networks of networks for operation in dynamic and contested environments. The program will address optimization within 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:*** - Develop 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. - Develop mission-based network architecture control and information delivery mechanisms.	-	-	8.000
Title: Fixed Wireless at a Distance ***Description:*** Unlike commercial wireless communications, the military cannot count on a set of secure, fixed cell towers to establish wireless networks capable of receiving and distributing large amounts of data from distributed sources. Rather, such communication must rely on approaches such as balloons and temporary communication towers that have a high logistical burden	5.500	4.000	-

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
and are extremely vulnerable. Building upon technologies investigated under other High-Capacity Links technologies programs within this project, the Fixed Wireless at a Distance program is overcoming these limitations by developing a re-locatable, long-range (10-100s of km) communication infrastructure that provides high-capacity (10s of megabits per second) data links from within a protected space. The key innovation in this program is the use of a large number of rapidly deployable, distributed, ground-based antenna arrays that can form a coherent aperture for directional transmission and reception of information to/from tactical wireless networks. Program challenges include the fundamental limits (power and extent) of transmitter gain as well as the rapid and practical deployment of the ground-based arrays. When completed, the Fixed Wireless at a Distance program will significantly extend the reach of tactical communication systems without the need for vulnerable and costly infrastructure. ***FY 2014 Accomplishments:*** - Field tested collaborative beam focusing radios to measure power as a function of speed. - Built prototype infrastructure module supporting 4 channels divided between a select legacy military waveform and a Computational Leverage Against Surveillance Systems (CLASS) extended range waveform. - Measured network performance improvement, throughput and pervasiveness, comparing Mobile Ad Hoc Network with Gateway and Fixed Wireless network protocol. ***FY 2015 Plans:*** - Developed self-organizing communications software to automatically configure distributed communication systems without operator configuration.			
Title: Mobile Hotspots ***Description:*** Communications requirements are growing 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 will develop an airborne high capacity data distribution network to interconnect groups of tactical users in a manner that is conceptually similar to the commercial tiered approach of interconnecting cell towers and wireless hotspots. Mobile Hotspots will exploit advances in millimeter-wave technology and airborne networking to develop a self-organizing, 1 Gb/s mobility 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 will be integrated with commercial and military communications equipment and mounted on tactical UAVs and ground vehicles to provide network access to mobile users via infrastructureless hotspots that are compatible with existing radios. The Mobile Hotspots program is targeted to transition to the Army and Marine Corps Expeditionary Forces. ***FY 2014 Accomplishments:***	17.678	14.650	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Manufactured antenna, amplifier, modem, and networking hardware needed to implement a self-organizing network comprising at least five hotspot nodes interconnected by 1 gigabit per second point-to-point millimeter-wave links to form a tactical airborne network. - Completed the design and began development of Mobile Hotspots prototype into pods for mounting on UAVs and tactical ground vehicles. - Began test planning for the Mobile Hotspot initial ground-based field experiment. ***FY 2015 Plans:*** - Evaluate initial capabilities of the Mobile Hotspot prototype network and millimeter-wave tactical airborne network in an initial ground-based field experiment. - Identify and implement system and subsystem improvements in preparation for final field experimentation and flight test. - Conduct ground testing of integrated air and ground vehicle systems to validate system operation and performance. - Conduct flight tests to evaluate system performance in various air-to-air, air-to-ground, and multi-node networking configurations.			
Title: Scalable Millimeter-wave (MMW) Architectures for Reconfigurable Transceivers (SMART) ***Description:*** The Scalable Millimeter-wave (MMW) Architectures for Reconfigurable Transceivers (SMART) program developed a new technology for producing very thin millimeter-wave array apertures and transceivers. The technology development culminated in the demonstration of a large-sized coherent, active electronically scanned array (AESA) with an output power density of 5W per square centimeter and a total layer thickness of less than one centimeter. As part of the High-Capacity Links efforts in this Project, the SMART technology approach resulted in a breakthrough in performance over conventional millimeter-wave approaches. The 3-D multi-layer assemblies developed will greatly reduce AESA packaging complexity and enable very compact, low-cost, millimeter-wave, and radio frequency circuit "building blocks" to combine to form arbitrarily large arrays. New capabilities, such as the ability to construct reconfigurable and/or multi-band AESAs and other MMW circuits, will be enabled by this architectural approach. The SMART program transitioned to industrial producers of MMW radar and communication system components for DoD applications. ***FY 2014 Accomplishments:*** - Developed high-yield processes for planarization and through-via fabrication. - Increased manufacturability and affordability of SMART baseline sub-array modules using cost-effective silicon and indium phosphide foundries for front-end device fabrication and back-end interconnect processes, leveraged high-speed pick and place bonding tools to improve accuracy and speed of module integration.	6.000	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Fabricated more than 10,000 indium phosphide power amplifiers and silicon beamformers for integration into SMART baseline sub-array modules for prototype demonstration.			
Title: Content-Based Mobile Edge Networking (CBMEN) ***Description:*** The CBMEN program's goal was to provide tactical warfighters operating at the edge with interactive, on-demand access to relevant information and a greater ability for real-time sharing of new operational content. This content can include images, video, maps, situational awareness, and command and control information. Advances in communications technologies are enabling high-capacity communications in remote environments. However, the current centralized or regional storage and dissemination of information presents reliability and capacity challenges with distributing relevant information to users at the edge. Commercial industry has developed approaches to the autonomous dissemination of high demand information by using distributed servers and advanced networking and information database technologies, combined with highly reliable fixed networking infrastructure that have embedded complex information exploitation tools. Unfortunately, the commercial system is enabled by infrastructure that is not available to the warfighter. This Advanced Networks technologies program leveraged commercial technologies to develop, prototype, and demonstrate the networking technologies and information dissemination techniques needed to enable efficient and robust content distribution using dynamic, mobile, and ad hoc military networks. CBMEN was installed and demonstrated on existing radios. Capabilities from this effort transitioned to the DoD. ***FY 2014 Accomplishments:*** - Developed objective metrics for advanced scenarios and simulation development for program evaluation and analysis. - Developed representative military small unit scenarios for simulations, over-the-air testing, demonstration, and transition. - Implemented CBMEN technologies for content naming, distribution, management, and security on handheld devices. - Demonstrated capabilities to transition partners in successive field experiments with increasing mobility, network size, content-rich applications, and content segregation based on access permissions using militarily relevant content in operationally relevant scenarios.	13.510	-	-
Title: Wireless Network after Next (WNaN) and Advanced Wireless Networks for the Soldier (AWNS) ***Description:*** The Wireless Network after Next (WNaN) and Advanced Wireless Networks for the Soldier (AWNS) program goals were to develop and demonstrate Advanced Networks technologies and system concepts that enable densely deployed radio networks to compensate for limitations of the physical layer of a low-cost wireless node. WNaN/AWNS networks managed node configurations and the topology of the network to reduce the demands on the physical and link layers of the network. The technology created by the WNaN/AWNS effort provided reliable and available battlefield communications at low system cost. AWNS also investigated the integration of Multi-User Detection (MUD) and Multiple-Input Multiple Output (MIMO) technology into the WNaN radio platform to position these technologies for transition into the WNaN radio node, as well as the Soldier Radio waveform (SRW) Anti-Jam (AJ) mode waveform. In addition, this effort investigated Wireless Distributive Computing	7.500	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
(WDC), Content Based Access (CBA), and smart antenna technologies to enhance the network and node ability to understand the operating environment, mission concept of operations, and node responsibilities to assist in data processing, information dissemination, and accomplishment of military mission objectives. Further, this program developed a low-cost handheld/body wearable wireless node that can be used to form high-density ad hoc networks and gateways to the Global Information Grid. This program also developed robust networking architecture(s) and network technologies/processes that exploit high-density node configurations. ***FY 2014 Accomplishments:*** - Completed demonstration of network scaling to support company-level utility and scalability to large numbers of nodes. - Completed network integration evaluations and field experiments with Marine Corps, Army, and Air Force to establish feasibility and utility for transition.			
Title: Communications Under Extreme RF Spectrum Conditions (CommEx) ***Description:*** The Communications Under Extreme RF Spectrum Conditions (CommEx) program developed signal detection and reasoning technology that allows radios to recognize interference and jamming attacks and then adapt to maintain communications, even in the presence of cognitive jammer attacks and dynamic interference of multiple cognitive network interactions. As part of Low Probability of Detection/Anti-Jam (LPD/AJ) technologies efforts in the Project, the program developed models of adversary, commercial, and friendly cognitive radios and implemented those models to assess, in real time, the current and future dynamics of the communications network. Core technologies for operation in highly dynamic and/or high jamming to signal environments were developed to include: automated jamming waveform forensics; local environment assessment (time, space, frequency, polarization); technologies for addressing known attack strategies and interference properties; and antenna, signal processing, modulation, and network optimization technologies. Based on predictions of the level of communication success compared to mission communication requirements, the cognitive radio chooses waveform selections/configurations that best achieve mission objectives. The cognitive radio includes the capability to analyze and select optimum frequency, waveform, and network configurations during all aspects of a mission. The design effort led to new radio communication architectures, more robust radio communication networking, and better understanding of optimization amongst interference avoidance and interference suppression strategies. This program also sought to enable communication between dispersed and distributed emitters and receivers to provide a multiplier in capacity for both locating emitters and assessing effectiveness of an electronic attack. Technologies developed in this program transitioned to the Navy and Air Force. ***FY 2014 Accomplishments:*** - Performed subsystem demonstrations in the laboratory that validated the performance and network overhead of systems that implement the principles developed in this program.	12.500	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Implemented technology and algorithms on specific radio hardware to confirm that implementation specifics can be transitioned and integrated into communication systems. - Developed architecture to allow CommEx technology to be inserted into radio platforms that will enable assessment of military utility. - Evaluated the application of CommEx principles on existing military systems. - Conducted laboratory evaluations and demonstrations using Link 16 communications systems to determine military utility.			
Accomplishments/Planned Programs Subtotals	141.023	135.561	115.265

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 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
CCC-04: *SECURE INFORMATION AND NETWORK SYSTEMS*	-	11.740	1.706	-	-	-	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

Computer and networking technologies have rapidly matured in the last decade with profound effect on the DoD and the nation. The Secure Information and Network Systems project will develop and demonstrate 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 will develop, integrate, and test technologies for re-using software components.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Rapid Software Development using Binary Components (RAPID) ***Description:*** The Rapid Software Development using Binary Components (RAPID) program will develop 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 out-dated operating systems, impacting operations. A companion applied research effort is budgeted in PE 0602303E, Project IT-03. RAPID capabilities will transition to the Services. ***FY 2014 Accomplishments:*** - Demonstrated the system to military users and conducted initial transition planning. - Participated in technology evaluation exercises with military stakeholders. - Supported transition partners in developing an initial software reuse concept of operations. ***FY 2015 Plans:*** - Transition system outputs based on results from technology evaluation exercises. - Deploy prototype systems at transition partner sites and support initial operations.	11.740	1.706	-
Accomplishments/Planned Programs Subtotals	11.740	1.706	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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

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 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	76.747	101.998	86.070	-	86.070	12.000	12.000	8.000	-	-	-

A. Mission Description and Budget Item Justification

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

B. Accomplishments/Planned Programs ($ in Millions)

	FY 2014	FY 2015	FY 2016
Title: Classified DARPA Program ***Description:*** This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2014 Accomplishments:*** Details will be provided under separate cover. ***FY 2015 Plans:*** Details will be provided under separate cover. ***FY 2016 Plans:*** Details will be provided under separate cover.	76.747	101.998	86.070
Accomplishments/Planned Programs Subtotals	76.747	101.998	86.070

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	261.613	360.426	452.861	-	452.861	470.582	407.944	407.772	405.418	-	-
NET-01: *JOINT WARFARE SYSTEMS*	-	37.273	43.828	61.787	-	61.787	100.520	129.808	187.094	195.117	-	-
NET-02: *MARITIME SYSTEMS*	-	44.975	86.120	113.868	-	113.868	105.062	107.802	141.344	151.301	-	-
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	179.365	230.478	277.206	-	277.206	265.000	170.334	79.334	59.000	-	-

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014**	**FY 2015**	**FY 2016 Base**	**FY 2016 OCO**	**FY 2016 Total**
Previous President's Budget	259.006	386.926	390.744	-	390.744
Current President's Budget	261.613	360.426	452.861	-	452.861
Total Adjustments	2.607	-26.500	62.117	-	62.117
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-26.500			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	9.863	-			
• SBIR/STTR Transfer	-7.256	-			
• TotalOtherAdjustments	-	-	62.117	-	62.117

Change Summary Explanation

FY 2014: Increase reflects reprogrammings offset by the SBIR/STTR transfer.
FY 2015: Decrease reflects congressional reduction.
FY 2016: Increase reflects expanded maritime systems efforts and an increase in classified programs.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
NET-01: *JOINT WARFARE SYSTEMS*	-	37.273	43.828	61.787	-	61.787	100.520	129.808	187.094	195.117	-	-

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 2014	FY 2015	FY 2016
Title: System of Systems Architecture, Technology Development, and Demonstration	-	15.000	34.986
Description: The System of Systems Architecture, Technology Development, and Demonstration 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 Plans:*** - Develop reference objective system of systems architecture.			

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Develop architecture demonstration plan, including range and platform options. - Implement M&S capabilities for architecture design analysis and validation. - Develop a System Integration Laboratory (SIL) to support government verification and validation of system of systems architectures. - Commence the development of system of systems synthesis and integration tools and protocols. - Commence development of engineering tools to validate system of system architecture designs. - Commence development of formal verification techniques to validate integration of constituent systems into a system of systems. - Investigate technologies to permit multi level security M&S. - Explore alternative systems architectures, designs, tools, and protocols for the maritime environment. ***FY 2016 Plans:*** - Complete the development of system of systems synthesis and integration tools and protocols. - Complete prototype architectures to implement the system of systems concept. - Initiate experimentation in constructive, virtual, and real-world environments to validate system of systems approach. - Assess in SIL the capability of new engineering tools to validate system of system 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 the SIL. - Develop technologies to permit multi level security M&S. - Identify the most promising alternative systems architectures, designs, tools, and protocols for the maritime environment.			
Title: Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE)* ***Description:*** *Formerly Integrated Planning for Strike, ISR, and Spectrum (IPSIS) 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	-	10.684	16.866

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
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 Plans:*** - Develop concept of operations (CONOPS) for an integrated strike, ISR, and spectrum management capability operating in an Air Operations Center (AOC). - Develop system architecture and software framework for integrated strike, ISR, and spectrum management to include planning, assessment, and dynamic replanning. - Develop models and simulation capability for testing, analysis, and validation of planning and assessment components. - Commence development of algorithms and prototypes for integrated planning and assessment components. ***FY 2016 Plans:*** - Complete development of algorithms and prototypes for integrated planning and assessment components. - Develop models and simulation capability for testing, analysis, and validation of integrated system. - Implement the framework designs into a software prototype. - Test and evaluate candidate software frameworks and components.			
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 algorithms that target an adversary by their emissions. - Identify phenomenological barriers (frequency, motion, and vibration) and validate transition opportunities.	-	-	9.935

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- 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 ground-to-air demonstration of capability.			
Title: High Energy Liquid Laser Area Defense System (HELLADS) ***Description:*** The goal of the HELLADS program is to develop a high-energy laser weapon system that will provide an order of magnitude reduction in weight compared to existing laser systems. HELLADS will enable high-energy lasers (HELs) to be integrated onto tactical aircraft and will significantly increase 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 will be explored. With the assistance of the Services, the HELLADS program will pursue 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. While the prototype laser weapon system module is in design and development, the HELLADS 150 kilowatt (kW) laser will be made available for demonstration opportunities and transition to the Army, Navy, or Air Force. ***FY 2014 Accomplishments:*** - Completed laboratory checkout and government acceptance of 150 kW laser; packaged laser and shipped for integration into the high power laser demonstrator system. - Continued risk reduction test of tracking systems for dynamic targets, demonstrated aim point accuracy to support lethal power delivery to test targets in representative battlefield environments. - Completed high power optics insertion, safety system checkouts, range communications protocol check, and initial high power static operation of laser weapon demonstrator to verify the laser and its subsystems can safely demonstrate lethal effects on mortars and rockets. - Commenced live fire tests against rocket and mortar fly-outs to demonstrate lethal laser power at mission-relevant ranges. - Completed preliminary design and detailed design of laser weapon module prototype's subsystems for integration on a specific air-, ground-, or sea-based tactical vehicle. ***FY 2015 Plans:*** - Complete live fire tests against rocket and mortar fly-outs to demonstrate lethal laser power at mission-relevant ranges. - Transport demonstrator laser from Army mission (rocket/mortar) relevant ground test site to mountain peak test site to mimic Air Force missions for precision air-to-ground and airborne self-defense demonstrations.	26.673	14.144	-

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Complete live fire target prosecution from mountain peak test site to demonstrate performance of laser weapon system in airborne missions, to include targeting of ground vehicles and self-defense against surface-to-air missiles.			
Title: Robotics Challenge ***Description:*** Advancements are being made in land-capable, high degree-of-freedom unmanned platforms to enable mobility over complex terrain. Many current prototypes are inspired by biological systems and while proof-of-principle systems have or are demonstrating unprecedented mobility, limitations have emerged. Advanced capabilities in perception, control, and physical capability/coordination are needed to work autonomously in human environments. These are critical enablers for performing mission-relevant tasks in austere and remote regions, partially-destroyed roads, high-threat anti-access/area denied environments, rubble-filled areas, and providing greater range/endurance for soldiers, platforms, and personnel. The Robotics Challenge program will boost innovation in autonomous systems and expand platform utility through enhanced actuation, energy density, perception, locomotion, agile reconfiguration, and design efficiency. Program thrusts are 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 consists of a series of obstacle course style challenge events that will focus on technology solutions to demonstrate and test robot capabilities for disaster response. Robotics Challenge events will drive advances in power systems, agility and speed, precision in perception tied to platform coordination, dexterity, and impulsive power. Program objectives focus 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 is budgeted in PE 0602702E Project TT-04. Anticipated Service users include the Army, Marines, and Special Forces. ***FY 2014 Accomplishments:*** - Coordinated Service participation in Robotics Challenge and applied simulation system to Service areas of interest. - Conducted DARPA Robotics Challenge Trials. - Extrapolated on and conducted further modeling and simulation of techniques and approaches for authentic applications with higher complexity. ***FY 2015 Plans:*** - Conduct DARPA Robotics Challenge Finals.	8.100	4.000	-
Title: Legged Squad Support System (LS3) ***Description:*** The Legged Squad Support System (LS3) program explored the development of a mission-relevant quadruped platform scaled to unburden the infantry squad and hence unburden the soldier. In current operations, soldiers carry upwards of 50lbs of equipment, in some cases over 100lbs, over long distances in terrain not always accessible by wheeled platforms that	2.500	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014**	**FY 2015**	**FY 2016**
support infantry. As a result, the soldier's combat effectiveness can be compromised. The LS3 program designed and developed technology demonstrators capable of carrying 400lbs of payload for 20 miles in 24 hours, negotiating terrain at endurance levels expected of typical squad maneuvers. LS3 leveraged technical breakthroughs of prior biologically inspired legged platform development efforts. It developed system designs to the scale and performance adequate for infantry squad mission applications, focusing on platform, control, and human-machine interaction capabilities, as well as secondary design considerations, such as acoustic signature. Anticipated Service users include the Army, Marines, and Special Forces. ***FY 2014 Accomplishments:*** - Supported and refined system prototypes. - Designed additional LS3 technology demonstrator to address novel approaches to energy consumption, increased survivability and reduced noise. - Participated in final demonstration activities in coordination with the U.S. Marine Corps. - Conducted endurance and reliability testing of final LS3 system.			
Accomplishments/Planned Programs Subtotals	37.273	43.828	61.787

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 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
NET-02: *MARITIME SYSTEMS*	-	44.975	86.120	113.868	-	113.868	105.062	107.802	141.344	151.301	-	-

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 2014	FY 2015	FY 2016
Title: Distributed Agile Submarine Hunting (DASH)	23.975	14.874	8.500
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 2014 Accomplishments: - Completed development of deep-sea prototypes system of distributed sonar nodes, both passive and active. - Completed development of distributed multi-node communication network for connectivity between seafloor, surface, and shore or ship. - Demonstrated extended remote monitoring capability of a passive sonar barrier network at sea. - Demonstrated Unmanned Undersea Vehicle (UUV)-based active sonar in a deep-sea test showing target detection and tracking.			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014**	**FY 2015**	**FY 2016**
- Integrated technologies for autonomous, reliable, and secure undersea energy and data transfers to fixed and mobile undersea systems. ***FY 2015 Plans:*** - Design and develop longer-duration passive and active sonar nodes. - Conduct extended-duration sonar demonstrations at sea against a target. - Demonstrate connectivity from seafloor node to remote shore station. - Integrate distributed communications with Navy systems for data transfer and Command, Control, Communications, Computers, and Intelligence (C4I). - Initiate test planning for passive and active sonar sea test. - Explore alternative concepts of operations and modified architectures of DASH system for other applications. ***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. - 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.			
Title: Hydra ***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 2014 Accomplishments:*** - Conducted studies to refine the operational trade space, define limits of current technology, and develop new technical approaches. - Initiated concept designs for the modular enclosure and potential payloads. - Explored innovative approaches for key enabling technologies such as energy storage, communications, and deployment. - Conducted risk reduction of key enabling technologies. - Investigated deployment options and initiated system conceptual design. ***FY 2015 Plans:***	14.000	28.898	32.868

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Complete concept designs for the modular enclosure and potential payloads. - Begin development of a prototype modular enclosure. - Begin development of undersea and air vehicle payloads. - Demonstrate enabling technologies and subsystems. ***FY 2016 Plans:*** - Build and test prototype modular enclosure. - Complete critical design review for undersea payload. - Complete critical design review for air vehicle payload. - Conduct initial flight test of the air vehicle. - Demonstrate submerged payload launch capability.			
Title: Hybrid Multi Material Rotor Full Scale Demonstration ***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 developed under the Hybrid Multi Material Rotor (HMMR) program budgeted in PE 0602715E, Project MBT-01, 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 Plans:*** - Conduct a Preliminary Design Review. - Complete manufacturing drawings and tooling. - Conduct a Critical Design Review. - Complete structural building block testing. - Complete shock building block testing. - Initiate manufacturing of the full-scale propulsor component to be installed on a Virginia Class submarine.	-	14.500	14.000

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Conduct a shock test of a large-scale model. ***FY 2016 Plans:*** - 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. - Provide integration support for the propulsor component.			
Title: Tactical Undersea Network Architecture* ***Description:*** *Formerly Undersea Architecture: Adaptive Infrastructure 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 within Project NET-02, the Tactical Undersea Network Architecture program will overcome these limitations by developing the technologies necessary for autonomous, reliable, and secure undersea energy and data transfers; true plug, play, and operating standards; and rapid, cost effective deployment and sustainment 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 Plans:*** - Commence system architecture design trade studies, modeling and simulation. - Commence small lightweight optical fiber development and fiber performance testing. - Assess system deployment and sustainment options; develop cost model. - Develop system component-level technologies and commence scaled component-level testing. ***FY 2016 Plans:*** - Complete system architecture design trade studies and preliminary design reviews. - Continue fiber performance testing; demonstrate fiber survivability under at-sea conditions. - Complete component-level testing.	-	14.300	19.500

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Commence prototype system design and sea test planning.			
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 by leveraging the powering and performance results from the previously funded Super-Fast Submerged Transport program, PE 0602702E, Project TT-03, 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: integration of reliable undersea connectivity, autonomy, guidance, and navigation; obstacle avoidance; and propulsion and energy systems compatible with existing manned platform safety requirements. The program will culminate in a series of at-sea demonstrations and will transition to the Navy. ***FY 2015 Plans:*** - Commence platform and module design and technology assessments and system safety and effectiveness modeling. - Establish baseline test platform architecture and conduct initial check-out testing. - Conduct system performance modeling and simulation and small scale laboratory trials. - Commence design safety certification test planning. ***FY 2016 Plans:*** - Commence sub-system hardware and software testing and module integration. - Update system performance models and conduct initial at-sea testing. - Commence safety certifications and testing.	-	13.548	16.000
Title: Long-Range Undersea Navigation ***Description:*** The Long-Range Undersea Navigation program will provide continuous, GPS-level positioning accuracy to submarines and autonomous undersea vehicles (AUVs) in long-range 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	-	-	12.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
systems (INS), but INS accuracy can degrade unacceptably over time. Building upon concepts explored under the Distributed Agile Submarine Hunting (DASH) program within Project NET-02 and the Upward Falling Payloads program, PE 0602702E, Project TT-03 the Long-Range Undersea Navigation 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:*** - Develop signal waveforms and preliminary designs for signal transmitters and receivers. - Develop the system concept of operations. - 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.			
Title: Multi-Axis Protection of Surface Ships ***Description:*** The anti-ship cruise missile (ASCM) is a growing asymmetric threat to U.S. naval combatants, force projection, and defense of the sea lanes of communications missions. Threat ASCM capabilities and lethality are rapidly improving with extended range, higher speeds, and advancing sophistication in navigation and targeting subsystems. In addition, these weapon systems are being proliferated in greater numbers to adversarial nations with options for submarine deployment. Submarine-launched ASCMs pose an even greater challenge to our Anti-Submarine Warfare (ASW) systems as they expand search area requirement proportional to the square of the cruise missile range. The Multi-Axis Protection of Surface Ships program intends to reverse the asymmetric advantage of these threats through the development of advanced offboard sensing from unmanned systems. These multi-spectral mobile and autonomous sensor systems will operate at significant offboard ranges from maritime battle groups to provide tactically significant early warning of cruise missile attacks. The effort is focused on achieving new detection modalities with sufficient low power, weight, and size (SWaP), to enable unmanned vessel implementations. Initial efforts will focus on identifying the best detection methods and sensor modalities leveraged from state-of-the-art sensors and new physical and operational insights. Provided compelling detection capability is achievable, prototype systems will evolve through at-sea testing and sensor integration. The program seeks to further explore ASW and networked maritime system concepts explored within PE 0603766E, Project NET-02, and PE 0602702E, Project TT-03, to develop breakthrough technology for long-range detection and classification, communications, energy management, sensor and platform integration, and robust autonomous processing and control for distributed sensing platforms. This program will transition to the Navy. ***FY 2016 Plans:***	-	-	11.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Define/develop system objectives and requirements. - Develop concept of operation for outer- and mid-zone defense. - Characterize tactical communications interface requirements. - Develop candidate systems concepts. - Analyze and evaluate candidate systems performance.			
Title: Structural Logic ***Description:*** The Structural Logic program developed platform structures and frames that can adapt to varying loads and simultaneously exhibit both high stiffness and high damping. This program demonstrated the utility of negative stiffness structural elements developed under the Multifunctional Materials and Structures program, budgeted in PE 0602715E, Project MBT-01, in the ridged support frames of real world DoD platforms. As the demands on military platforms increase, so does the need for structures to mitigate the shock and vibrations applied by dynamic environments. Today's structures exhibit limited adaptability and typically achieve either extreme stiffness or damping. In military platforms, extremely stiff structures provide high strength, but readily transfer loads to passengers often resulting in serious injury. Conversely, existing damping structures can reduce the load transferred to passengers, but only at the expense of structural strength and integrity. By demonstrating the ability to combine stiffness, damping, and dynamic range in a single structure, the Structural Logic program enabled the design of military platforms with the ability to continually adapt their properties to match the demands of a dynamic environment. Technology from this program transitioned to the Navy. ***FY 2014 Accomplishments:*** - Completed construction of sub-scale high-speed planing boat incorporating negative stiffness elements; performed system testing and evaluation with Navy partners, demonstrating the technology in a realistic environment.	7.000	-	-
Accomplishments/Planned Programs Subtotals	44.975	86.120	113.868

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 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	179.365	230.478	277.206	-	277.206	265.000	170.334	79.334	59.000	-	-

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 2014	FY 2015	FY 2016
Title: Classified DARPA Program ***Description:*** This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2014 Accomplishments:*** Details will be provided under separate cover. ***FY 2015 Plans:*** Details will be provided under separate cover. ***FY 2016 Plans:*** Details will be provided under separate cover.	179.365	230.478	277.206
Accomplishments/Planned Programs Subtotals	179.365	230.478	277.206

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603767E *I SENSOR TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	268.754	302.821	257.127	-	257.127	275.921	240.658	198.129	203.195	-	-
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	43.317	34.563	19.901	-	19.901	15.554	9.734	8.798	13.672	-	-
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	110.248	115.004	114.396	-	114.396	160.697	157.194	153.098	170.387	-	-
SEN-03: *EXPLOITATION SYSTEMS*	-	36.910	58.464	28.664	-	28.664	40.323	40.696	30.136	19.136	-	-
SEN-06: *SENSOR TECHNOLOGY*	-	78.279	94.790	94.166	-	94.166	59.347	33.034	6.097	-	-	-

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014**	**FY 2015**	**FY 2016 Base**	**FY 2016 OCO**	**FY 2016 Total**
Previous President's Budget	276.364	312.821	279.927	-	279.927
Current President's Budget	268.754	302.821	257.127	-	257.127
Total Adjustments	-7.610	-10.000	-22.800	-	-22.800
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-10.000			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	0.560	-			
• SBIR/STTR Transfer	-8.170	-			
• TotalOtherAdjustments	-	-	-22.800	-	-22.800

Change Summary Explanation

FY 2014: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.

FY 2015: Decrease reflects congressional reduction.

FY 2016: Decrease reflects completion of Adaptable Navigation Systems (ANS), Adaptable, Low Cost Sensors (ADAPT), and Behavioral Learning for Adaptive Electronic Warfare (BLADE) programs.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	43.317	34.563	19.901	-	19.901	15.554	9.734	8.798	13.672	-	-

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 2014	FY 2015	FY 2016
Title: Multi-Function Optical Sensing	20.000	19.060	19.901
Description: The proliferation of radio frequency (RF)-based countermeasures, such as digital radio frequency memory (DRFM), has presented challenges to the effectiveness of data sensors. The Multi-Function 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-function optical 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 2014 Accomplishments: - Completed design of prototype sensor through critical design review. - Initiated development of a first-generation prototype sensor. - Incorporated results of concept of operations and algorithm performance on simulated data to refine objective system performance requirements. - Initiated investigation of communications protocols for the multi-optical sensor to interact with other systems and platforms. - Continued development of sensor data-processing algorithms to improve target tracking and identification. - Initiated advanced system signal-processing methodologies for real-time performance and integration into the second-generation sensor system.			

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Investigated alternative approaches for an active cueing system. ***FY 2015 Plans:*** - Complete the development of the first-generation prototype system. - Incorporate advanced data-processing and target tracking algorithms into the sensor processing chain. - Initiate packaging activity for the incorporation of the developed active focal plane arrays and variable-waveform lasers into the second-generation architecture. - Develop 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:*** - Perform air-to-air demonstrations with the first-generation prototype system. - Initiate the development of a second-generation prototype sensor, which will demonstrate the full capability out to operational ranges. - Commence the development of the second-generation prototype sensor.			
Title: Adaptable Navigation Systems (ANS) ***Description:*** The Adaptable Navigation Systems (ANS) program will provide the U.S. warfighter with the ability to effectively navigate all 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 relies on three major technology innovations. The first is development of a new type of inertial measurement unit (IMU) that requires 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 uses 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. These will be received on the Services' forthcoming software-defined radios and will use specially tailored algorithms to determine position. The third technology innovation allows 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 will enhance 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 will build 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. If successful, major improvements in navigation accuracy and system cost could also be realized. Early transition partners would include all Services, with emphasis on platforms and users that must operate in multiple environments, such as Naval forces. ***FY 2014 Accomplishments:***	14.571	9.779	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Completed development of candidate filter, sensor, and architecture design for plug-and-play system. - Demonstrated flexible, real-time operation of ANS systems on sea-, air-, and land-based platforms using relevant sensor suites. - Transitioned novel navigation measurement technologies, via new sensors, algorithms, or measurement enhancements, into ANS demonstration systems. - Evaluated options for size, weight, power, and cost (SWaP-C)-constrained reference stations that enable full SoOp-based navigation. - Completed design of second-generation 6-degree-of-freedom cold atom IMU. - Evaluated candidate approaches for a wireless time transfer and positioning system that provides GPS-level performance globally with minimal infrastructure, and a compact, jam-proof PNT sensor that provides better than GPS-level performance. ***FY 2015 Plans:*** - Test and evaluate first-generation 6-degree-of-freedom cold atom-based IMU. - Demonstrate inertial navigation performance of a second-generation cold atom-based IMU on a submarine platform. - Demonstrate 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 to effect transition to the Services.			
Title: Adaptable, Low Cost Sensors (ADAPT) ***Description:*** The objective of the Adaptable, Low Cost Sensors (ADAPT) program is 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 Smart Munitions effort plans to use 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 seeks to develop a reference design to demonstrate capability and develop tactics for unattended sensors. This program will transition to the Services. ***FY 2014 Accomplishments:*** - Developed additional reference designs, including Quad-rotor UAV, Fixed Wing UAV, Unmanned Undersea Vessel (UUV), and Software-Defined Radio. - Configured hardware for heterogeneous distributed sensor mission.	8.746	5.724	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Field tested Smart Munitions with multiple sensor modalities. ***FY 2015 Plans:*** - Field test and demonstrate mobile coordinated device operation using ADAPT reference designs (Smart Munitions and UAVs). - Investigate alternative low cost sensor designs for other small form factor unmanned military platforms. - Transition reference designs to Services.			
Accomplishments/Planned Programs Subtotals	43.317	34.563	19.901

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 2016 Defense Advanced Research Projects Agency			Date: February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	110.248	115.004	114.396	-	114.396	160.697	157.194	153.098	170.387	-	-

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 2014	FY 2015	FY 2016
Title: Adaptive Radar Countermeasures (ARC)	19.221	27.975	19.500

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 the Joint Program Office.

FY 2014 Accomplishments:
- Completed detailed system architecture design and validated software interfaces.
- Conducted offline testing to demonstrate signal analysis and characterization of unanticipated or ambiguous radar signals.
- Assessed countermeasure effectiveness from over-the-air observable changes in the threat radar signals.
- Developed methodologies for closed-loop system testing against adaptive radar threats.
- Obtained commitments from transition partners to provide baseline hardware and software for integration and testing of algorithms in a laboratory environment.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Developed enhanced security structure for transitioning ARC technology to Joint Program Office transition. ***FY 2015 Plans:*** - Refine and integrate component algorithms for end-to-end system testing in a hardware-in-the-loop laboratory environment. - Begin porting software algorithms onto transition partner provided baseline EW systems to demonstrate enhanced performance against unknown or ambiguous threat radars. - Develop detailed flight test plans in concert with relevant programs of record and Service partners. ***FY 2016 Plans:*** - Complete real-time software and firmware implementation of all major algorithm modules on transition partner provided baseline EW systems. - Develop 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.			
Title: Multifunction RF ***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 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, 3) Implementation of software development kit to re-define modes as required by mission or platform needs; ease of adding new modes via software without hardware modifications. The program is planned for transition to the Army and Marines. ***FY 2014 Accomplishments:*** - Finalized tile array and array backplane technology selection for sub-array builds. - Began fabrications of sub-arrays for ARMS laboratory demo. - Demonstrated integration of silicon-based tile sub-array and digital receiver/exciter backplane.	23.954	16.575	9.385

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Demonstrated radar software development kit suitable for redefining system functions of integrated system. ***FY 2015 Plans:*** - Demonstrate utility of software development kit through third-party programming. - Complete laboratory testing of ARMS for flight testing. - Conduct laboratory demo with integrated ARMS, synthetic vision backbone, and multifunction software development kit. - Investigate alternative imaging radar architectures to further reduce size, weight, power, and cost. ***FY 2016 Plans:*** - 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 a UH-60 Black Hawk helicopter.			
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). ***FY 2014 Accomplishments:*** - Completed development of transmitter and receiver components for sensor demonstration. - Initiated hardware design and development of ViSAR system. - Demonstrated performance of laboratory quality objective transmitter amplifier. - Completed phenomenology models to support system simulations. ***FY 2015 Plans:*** - Complete development of flight-worthy high power amplifier. - Demonstrate the integration of low power transmitter and receiver components into sensor. - Integrate phenomenology data into scene simulator and generate data for demonstration of algorithm performance. ***FY 2016 Plans:*** - Integrate hardware into a sensor control system (gimbal) and demonstrate performance in a laboratory scenario.	19.250	17.990	15.250

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Integrate hardware and gimbal on a surrogate aircraft. - Conduct flight tests to demonstrate ViSAR performance in comparison to Electro-Optic sensors.			
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. Several 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 Air Force and SOCOM. ***FY 2014 Accomplishments:*** - Completed packaging of the high-power pulsed laser required for the MIST long-range prototypes. - Commenced long-range 3-D imaging prototype design and development. - Developed most promising crosswind sensor technologies. - Developed, tested, and transitioned near-hypervelocity rounds for snipers. - Investigated alternate uses of crosswind sensor technology. ***FY 2015 Plans:*** - Complete and transition the short-range 3-D imaging prototypes and technology to the Services. - Complete brassboard and ground demonstrations of the long-range 3-D imaging systems, including testing and demonstration of critical subsystem components. - Complete and test prototypes of the long-range 3-D imaging systems through airborne demonstrations. - Complete packaging and testing of the flight qualified MIST laser. ***FY 2016 Plans:*** - Conduct mountain-to-ground demonstration out to operationally relevant ranges. - Transition the long-range MIST systems to the Air Force.	29.723	23.964	4.761
Title: Spatial, Temporal and Orientation Information for Contested Environments (STOIC)	-	12.500	22.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Description: *Formerly Precision Timing Enabling Cooperative Effects Building on technologies developed in the Adaptable Navigation Systems 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 cold atom-based clocks and optical time transfer. Other recent advances show that navigation systems using non-traditional sensors can be rapidly configured to provide accurate positioning, navigation, and timing (PNT) capabilities. This program will build on these and other PNT technologies, and extend this level of performance to include the underwater environment in addition to surface, indoor, and airborne environments. 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 Plans:*** - Begin developing a compact optical clock that maintains GPS-level time for over a year. - Begin developing a wireless precision time transfer system that provides better than GPS-level performance using multifunctional systems (e.g. radars, imagers, communications). - Begin developing jam-proof PNT systems that provide better than 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. - 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. - 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.			
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	-	11.000	17.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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. Three core areas the program will focus on are: development of on-line adaptive algorithms that enable performance-driven sensing and ATR; recognition technology that enables rapid incorporation of new targets; and 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 Plans:*** - Develop a modeling and simulation framework for testing and evaluating performance-driven ATR systems. - Establish baseline performance for existing radar ATR algorithms against challenge problem data sets. - Design and execute a data collection experiment to provide additional data for algorithm development and testing. - Initiate 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.			
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; 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. Applications evaluated to date have identified transition opportunities with Special Operations Command and the Navy in force protection. ***FY 2016 Plans:***	-	-	10.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Develop sensor design concepts and processing algorithms. - Develop a prototype electronic sub-reflector beam-steering system and conduct tests to characterize performance and validate the approach. - Conduct mission studies and determine the system performance metrics required to support specific military applications.			
Title: Small Satellite Sensors ***Description:*** Building upon low cost and small form factor sensor research conducted under DARPA's ADAPT and Multi-Function Optical Sensing 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 subsystems. - Develop software performance models for candidate sensor systems, and perform laboratory and airborne testing to improve model fidelity and assist in selection of flight hardware. - Begin design of experimental sensor payloads compatible with a small satellite bus, and perform preliminary design review. - Begin development of unique component and subsystem technologies needed to support on-orbit demonstrations. - Investigate alternative low-cost payloads suitable for integration on a small satellite.	-	-	8.000
Title: Low Cost Seeker ***Description:*** The Low Cost Seeker program will develop novel weapon terminal sensing and guidance technologies and systems, for air-launched and air-delivered weapons, that can (i) find and identify fixed and moving targets with only minimal external support, (ii) achieve high accuracy in a GPS-denied environment, and (iii) 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 passive EO/IR sensors,	-	-	8.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
which have evolved into very small and inexpensive devices in the commercial market, and the reconfigurable processing architecture developed in DARPA's ADAPT program (budgeted in PE 0603767E, Project SEN-01). The technical approach to target identification will start from "deep learning" 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:*** - Develop small size, weight, and power (SWaP) and cost sensor and processing unit. - Design novel target identification algorithms. - Integrate feature-based navigation (non-GPS) with the small SWaP sensors/processing unit. - Conduct laboratory demonstrations of integrated sensor/processing unit.			
Title: Behavioral Learning for Adaptive Electronic Warfare (BLADE) ***Description:*** The Behavioral Learning for Adaptive Electronic Warfare (BLADE) program will develop the capability to jam adaptive and rapidly evolving radio frequency (RF) threats in tactical environments and at tactically-relevant timescales. This will change the paradigm for responding to evolving threats from lab-based manual development to an adaptive in-the-field systems approach. When an unknown or advanced RF threat appears, BLADE networked nodes will dynamically characterize the emitter, synthesize an effective countering technique, and evaluate jamming effectiveness by iteratively probing, learning, and adapting to the threat. An optimization process will tailor real-time responses to specific threats, producing a countermeasure waveform that maximizes jam effectiveness while minimizing the required jamming resources. Thus BLADE will enable the rapid defeat of new RF threats and provide the warfighter with real-time feedback on jam effectiveness. The program is transitioning to the U.S. Army Communications-Electronic RDT&E Center, Intelligence and Information Warfighter Directorate for further maturation and hardening. ***FY 2014 Accomplishments:*** - Performed test and evaluation of real-time prototypes in a laboratory environment based on Government provided threat networks that exhibited spectrum agility. - Successfully integrated algorithms into a prototype communication countermeasures system (CCS). - Extended and enhanced algorithms for over-the-air mobile operations involving dynamic battlefield conditions and cluttered RF environments. - Demonstrated accurate real-time electronic warfare battle damage assessment for transition partner defined threat networks. - Conducted open air ground testing at the U.S. Army Electronic Proving Grounds, Ft Huachuca, AZ. - Transitioned BLADE Phase II software algorithms to U.S. Navy Naval Surface Warfare Center Crane Maritime Expeditionary Division for use in the Standalone High Accuracy response Path (SHARP) project. ***FY 2015 Plans:***	18.100	5.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Formally test and evaluate ground-based and airborne prototype systems in an operationally relevant environment featuring agile threat networks. - Quantify the minimum hardware requirements, including processing and memory, necessary to execute the BLADE algorithms on transition platforms. - Transition BLADE components to U.S. Army Communications-Electronic RDT&E Center Intelligence and Information Warfare Directorate.			
Accomplishments/Planned Programs Subtotals	110.248	115.004	114.396

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 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
SEN-03: *EXPLOITATION SYSTEMS*	-	36.910	58.464	28.664	-	28.664	40.323	40.696	30.136	19.136	-	-

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 also addresses issues such as trustworthiness and provenance of that information. 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 2014	FY 2015	FY 2016
Title: Insight ***Description:*** Insight is developing the next generation multi-intelligence exploitation and resource management 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 detection of threat networks through combination and analysis of information from imaging and non-imaging sensors and other sources. The technical approach emphasizes model-based correlation, adversary behavior modeling, threat network analysis tools, resource management 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, on-line learning, and distributed social intelligence. 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, the Air Force Intelligence, Surveillance, and Reconnaissance Agency, National Air and Space Intelligence Center, and the Air Force Research Laboratory. Insight provides a unified architecture for plug-and-play ISR with extensibility to all Services and Combatant Commands, initially the Central, Special Operations, and Pacific Commands. ***FY 2014 Accomplishments:*** - Finalized formal transition agreements for transfer of technologies to Army and Air Force. - Demonstrated updated/improved and new analytical capabilities to support offensive, defensive, and stability operations during a live field test and in the context of an Army Brigade training rotation. - Developed new virtual sensor models and developed a complex virtual environment scenario for test, integration and validation prior to live test events.	36.910	43.534	11.664

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Augmented and demonstrated the reasoning component of the system to process various new and other relevant information sources (simulated and live) in support of contemporary mission profiles and operational environments. - Tested and matured advanced fusion technologies in live and virtual operational environments. - Tailored component and system level capabilities to specific transition partner objectives, software, data and workflows and demonstrated improvements in analytical effectiveness. ***FY 2015 Plans:*** - Complete the initial software baseline insertion and transfer technologies to Army and Air Force. - Continue to augment, refine and adapt algorithms and software baseline in preparation for second capability insertion to Army and Air Force. - Adapt capabilities to emerging operational environments, to include integration of additional, non-traditional sensors and information sources. - Test and mature advanced analytic and resource management technologies in live and virtual operational environments. - Execute a live field test in coordination with a military training rotation to demonstrate improvements and maturity of system capabilities in a dynamic operational environment. - Develop a new and advanced data model compatible with existing system data models. - Deliver refined, advanced and integrated capabilities that address key performance parameters of transition partner programs of record aligned with their software release cycles. ***FY 2016 Plans:*** - Test advanced analytic and resource management technologies in coordination with a military training rotation to demonstrate improvements and maturity of system capabilities. - Tailor final component and system level capabilities to specific transition partner objectives. - Deliver final integrated capabilities that address key performance parameters of transition partner programs of record for insertion into software baselines. - Prepare and finalize software packages and documentation for transition to Services.			
Title: Media Forensics* ***Description:*** *Formerly Battlefield Evidence The Media Forensics 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 for authentication and verification are manpower intensive and require analysts and investigators to undertake painstaking analyses to establish context and provenance. Media Forensics will develop, integrate, and extend image and video analytics to provide forensic information that can be used by analysts and automated systems. Technologies will transition to operational commands and the intelligence community.	-	14.930	17.000

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
FY 2015 Plans: - Formulate approaches to automatically detect when image and video files have been altered or manipulated. - Develop operator-in-the-loop technologies for analyzing and determining the trustworthiness of open source and collected images and video. - Initiate development of techniques for detection of information sources not consistent with other observations, indicative of possible disinformation efforts. ***FY 2016 Plans:*** - Develop advanced techniques for media fingerprinting and the ability to search large repositories for content produced by the same device. - Develop cross media representations of semantic content in image and video sources and techniques to combine information indicating where the sources reinforce or contradict each other. - Develop approaches for countering evolving anti-forensics technologies.			
Accomplishments/Planned Programs Subtotals	36.910	58.464	28.664

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.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
SEN-06: *SENSOR TECHNOLOGY*	-	78.279	94.790	94.166	-	94.166	59.347	33.034	6.097	-	-	-

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 2014	FY 2015	FY 2016
Title: Classified DARPA Program ***Description:*** This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2014 Accomplishments:*** Details will be provided under separate cover. ***FY 2015 Plans:*** Details will be provided under separate cover. ***FY 2016 Plans:*** Details will be provided under separate cover.	78.279	94.790	94.166
Accomplishments/Planned Programs Subtotals	78.279	94.790	94.166

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Details will be provided under separate cover.

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Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	80.025	-	-	-	-	-	-	-	-	-	-
SB-01: *SMALL BUSINESS INNOVATION RESEARCH*	-	80.025	-	-	-	-	-	-	-	-	-	-
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	-	-	-	-	-
Current President's Budget	80.025	-	-	-	-
Total Adjustments	80.025	-	-	-	-
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	80.025	-			

Change Summary Explanation

FY 2014: Increase reflects the SBIR/STTR transfer.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: Small Business Innovation Research ***Description:*** The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are designed to provide small, high-tech businesses and academic institutions the opportunity to propose radical, innovative, high-risk 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.	80.025	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	Date: February 2015
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605502E I *SMALL BUSINESS INNOVATION RESEARCH*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
FY 2014 Accomplishments: - The DARPA SBIR and STTR were executed within OSD guidelines.			
Accomplishments/Planned Programs Subtotals	80.025	-	-

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	71.659	71.362	71.571	-	71.571	73.539	75.501	77.306	77.684	-	-
MH-01: *MANAGEMENT HQ - R&D*	-	71.659	71.362	71.571	-	71.571	73.539	75.501	77.306	77.684	-	-
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. The funds provide personnel compensation for civilians as well as costs for building rent, physical security, travel, supplies and equipment, communications, printing and reproduction.

B. Program Change Summary ($ in Millions)

	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total
Previous President's Budget	71.659	71.362	72.390	-	72.390
Current President's Budget	71.659	71.362	71.571	-	71.571
Total Adjustments	-	-	-0.819	-	-0.819
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-	-			
• TotalOtherAdjustments	-	-	-0.819	-	-0.819

Change Summary Explanation

FY 2014: N/A
FY 2015: N/A
FY 2016: Decrease reflects minor program repricing.

C. Accomplishments/Planned Programs ($ in Millions)

	FY 2014	FY 2015	FY 2016
Title: Management Headquarters ***Description:*** Management Headquarters	71.659	71.362	71.571

Exhibit R-2, RDT&E Budget Item Justification: PB 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014**	**FY 2015**	**FY 2016**
FY 2014 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 2015 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 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.			
Accomplishments/Planned Programs Subtotals	71.659	71.362	71.571

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.