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.

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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

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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

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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

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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

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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	-

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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	-	-

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

COST ($ in Millions)	Prior Years	FY 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).

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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	22.665	18.734	22.900
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,			

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

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.

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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	26.159	18.749	19.633
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.			

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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	9.668	6.000	12.500
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			

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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

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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

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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

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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	-	9.500	15.000
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.			

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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	12.500	-	-
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.			
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.

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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
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.

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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

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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.

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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	-	12.554	23.000
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			

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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

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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	-

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
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.

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

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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

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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	23.700	13.000	10.250
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			

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
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)	-	-	12.000
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.			

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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

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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)	-	-	4.500
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-			

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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

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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.			

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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	-

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
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.

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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	-	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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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.

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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.			

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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)	31.000	25.000	-
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.			

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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	-	-	12.000
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.			
Title: Vertical Take-Off and Landing (VTOL) Technology Demonstrator	-	-	48.000
Description: The Vertical Take-Off and Landing (VTOL) Technology Demonstrator program will demonstrate revolutionary improvements in (heavier than air) VTOL air vehicle capabilities and efficiencies through the development of subsystem and component technologies, aircraft configurations and system integration. The program will build and flight test an unmanned 10,000 - 12,000 lb aircraft capable of sustained speeds in excess of 300 kt, demonstrate system level hover efficiency within 25 percent of the ideal, 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			

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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.

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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

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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	57.500	55.000	19.000
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.			

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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.

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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

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 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

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	-	-

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
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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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 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*

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.

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 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*

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)	28.259	14.264	-
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.			

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.

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

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

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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)	2.000	2.000	2.000
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:***			

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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	-	-

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
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.

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
- 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

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
- 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

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 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.

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
- 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)	28.325	24.600	-
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.			

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
- 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	4.033	18.000	18.000
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:***			

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
- 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)	-	-	8.000
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.			

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
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

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
- 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	-

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
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	-

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
- 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)	6.000	-	-
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.			

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
- 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
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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)	11.740	1.706	-
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.			
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	76.747	101.998	86.070
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.			
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.			

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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

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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

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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)	26.673	14.144	-
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.			

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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	-	-

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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.

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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
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.

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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

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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	-	14.500	14.000
Description: The goal of the Hybrid Multi Material Rotor Full-Scale Demonstration (HyDem) program is to dramatically improve U.S. Navy submarine superiority. HyDem will apply breakthroughs in materials and material system technologies 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.			

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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*	-	14.300	19.500
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.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Commence prototype system design and sea test planning.			
Title: Blue Wolf	-	13.548	16.000
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.			
Title: Long-Range Undersea Navigation	-	-	12.000
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			

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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

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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	7.000	-	-
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.			
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	179.365	230.478	277.206
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.			
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* / BA 3: *Advanced Technology Development (ATD)*					R-1 Program Element (Number/Name) PE 0603767E / *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)	14.571	9.779	-
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:***			

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
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
- 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	23.954	16.575	9.385
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.			

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
- 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)	29.723	23.964	4.761
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.			
Title: Spatial, Temporal and Orientation Information for Contested Environments (STOIC)	-	12.500	22.500

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 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

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

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
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

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
- 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
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
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
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
- 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			
Appropriation/Budget Activity 0400 / 3					R-1 Program Element (Number/Name) PE 0603767E / *SENSOR TECHNOLOGY*				Project (Number/Name) SEN-03 / *EXPLOITATION SYSTEMS*			
COST ($ in Millions)	**Prior Years**	**FY 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	36.910	43.534	11.664

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.

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
- 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	78.279	94.790	94.166
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.			
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	80.025	-	-
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.			

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*

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	71.659	71.362	71.571
Description: Management Headquarters			

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.