Exhibit R-2, RDT&E Budget Item Justification: PB 2015 Defense Advanced Research Projects Agency											Date: March 2014	
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*					R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*							
COST ($ in Millions)	**Prior Years**	**FY 2013**	**FY 2014**	**FY 2015 Base**	**FY 2015 OCO #**	**FY 2015 Total**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**Cost To Complete**	**Total Cost**
Total Program Element	-	273.750	315.033	312.146	-	312.146	322.923	340.207	340.784	342.847	-	-
BLS-01: *BIO/INFO/MICRO SCIENCES*	-	31.068	24.871	21.148	-	21.148	16.250	14.425	13.285	13.925	-	-
CCS-02: *MATH AND COMPUTER SCIENCES*	-	67.762	91.022	114.290	-	114.290	133.812	130.729	136.551	138.657	-	-
CYS-01: *CYBER SCIENCES*	-	17.095	26.333	28.627	-	28.627	28.000	12.000	12.000	8.000	-	-
ES-01: *ELECTRONIC SCIENCES*	-	43.349	44.354	30.327	-	30.327	35.876	35.376	34.912	33.502	-	-
MS-01: *MATERIALS SCIENCES*	-	80.326	85.819	85.527	-	85.527	75.624	87.777	82.423	85.763	-	-
TRS-01: *TRANSFORMATIVE SCIENCES*	-	34.150	42.634	32.227	-	32.227	33.361	59.900	61.613	63.000	-	-

The FY 2015 OCO Request will be submitted at a later date.

A. Mission Description and Budget Item Justification

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

The Bio/Info/Micro Sciences project will explore and develop potential technological breakthroughs that exist at the intersection of biology, information technology and micro/physical systems to exploit advances and leverage fundamental discoveries for the development of new technologies, techniques and systems of interest to the DoD. Programs in this project will draw upon information and physical sciences to discover properties of biological systems that cross multiple biological architectures and functions, from the molecular and genetic level through cellular, tissue, organ, and whole organism levels.

The Math and Computer Sciences project supports long term national security requirements through scientific research and experimentation in new computational models and mechanisms for reasoning and communication in complex, interconnected systems. The project is exploring novel means of exploiting computer capabilities, including: practical, logical, heuristic, and automated reasoning by machines; development of enhanced human-to-computer and computer-to-computer interaction technologies; innovative approaches to the composition of software; innovative computer architectures; mathematical programs and their potential for defense applications; and new learning mechanisms for systematically upgrading and improving these capabilities.

Exhibit R-2, RDT&E Budget Item Justification: PB 2015 Defense Advanced Research Projects Agency	Date: March 2014
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*

The Cyber Sciences project supports long term national security requirements through scientific research and experimentation in cybersecurity. Networked computing systems control virtually everything, from power plants and energy distribution, transportation systems, food and water distribution, financial systems, to defense systems. Protecting the infrastructure on which these systems rely is a national security issue. The Cyber Sciences project will ensure DoD cyber-capabilities survive adversary attempts to degrade, disrupt, or deny military computing, communications, and networking systems. Basic research in cyber security is required to provide a basis for continuing progress in this area. Promising research results will transition to both technology development and system-level projects.

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

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

The Transformative Sciences project supports scientific research and analysis that leverages converging technological forces and transformational trends in the areas of computing and the computing-reliant subareas of social sciences, life sciences, manufacturing, and commerce as a means of improving military adaptation to sudden changes in requirements, threats, and emerging converging trends.

B. Program Change Summary ($ in Millions)	FY 2013	FY 2014	FY 2015 Base	FY 2015 OCO	FY 2015 Total
Previous President's Budget	309.051	315.033	310.494	-	310.494
Current President's Budget	273.750	315.033	312.146	-	312.146
Total Adjustments	-35.301	-	1.652	-	1.652
• Congressional General Reductions	-0.407	-			
• Congressional Directed Reductions	-22.828	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-4.014	-			
• SBIR/STTR Transfer	-8.052	-			
• TotalOtherAdjustments	-	-	1.652	-	1.652

Change Summary Explanation

FY 2013: Decrease reflects Congressional reductions for Sections 3001 & 3004, sequestration adjustments, reprogrammings, and the SBIR/STTR transfer.
FY 2015: Increase reflects minor program repricing.

Exhibit R-2A, RDT&E Project Justification: PB 2015 Defense Advanced Research Projects Agency			Date: March 2014
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) BLS-01 / *BIO/INFO/MICRO SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2013	FY 2014	FY 2015 Base	FY 2015 OCO #	FY 2015 Total	FY 2016	FY 2017	FY 2018	FY 2019	Cost To Complete	Total Cost
BLS-01: *BIO/INFO/MICRO SCIENCES*	-	31.068	24.871	21.148	-	21.148	16.250	14.425	13.285	13.925	-	-

The FY 2015 OCO Request will be submitted at a later date.

A. Mission Description and Budget Item Justification

This project is investigating and developing the intersections of biology, information technology and micro/physical systems to exploit important technological advances and leverage fundamental discoveries for the development of new technologies, techniques, and systems of interest to the DoD. This research is critical to the development of rapid responses to engineered biological warfare agents, radically new biomolecular computers, improved training and cognitive rehabilitation, and novel materials for the DoD. Programs in this project will draw upon the information and physical sciences to discover properties of biological systems that cross multiple scales of biological architecture and function, from the molecular and genetic level through cellular, tissue, organ, and whole organism levels. This project will develop the basic research tools in biology that are unique to the application of biological-based solutions to critical Defense problems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
Title: Bio Interfaces	12.000	11.832	8.233
Description: The Bio Interfaces program supports scientific study and experimentation, emphasizing the interfaces between biology and the physical and mathematical/computer sciences. This unique interaction will develop new mathematical and experimental tools for understanding biology in a way that will allow its application to a myriad of DoD problems. These tools will help exploit advances in the complex modeling of physical and biological phenomena. It is also expected that understanding the fundamentals of biology will aid in developing tools to understand complex, non-linear networks. This program will also explore the fundamental nature of time in biology and medicine. This will include mapping basic clock circuitry in biological systems from the molecular level up through unique species level activities with a special emphasis on the applicability to human biology. Operational relevance of this research activity includes improving our understanding of sleep-wake cycles, increasing the scientific understanding of deployment cycle lengths, and enhancing our ability to model the dynamics of disease outbreaks.			
FY 2013 Accomplishments: - Defined spatio-temporal components and signatures by creating experimental test platforms and assays that will stress and perturb the system to confirm contributions of temporal regulators. - Initiated the development of algorithms designed to predict pertinent time processes active in biological systems (e.g., sleep cycles, metabolic cycles, and disease outbreak cycles). - Refined temporal signature networks and libraries that dictate temporal process regulation for determination of minimal datasets necessary for validated models.			

Exhibit R-2A, RDT&E Project Justification: PB 2015 Defense Advanced Research Projects Agency		Date: March 2014
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** BLS-01 / *BIO/INFO/MICRO SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Developed and validated algorithms of temporal processes associated with developmental processes in prokaryotic and eukaryotic systems. ***FY 2014 Plans:*** - Experimentally validate canonical spatio-temporal episequences, and develop a minimal dataset for accurate predictions of temporal processes such as cell cycle progression, metabolic cycles, and lifespan. - Refine predictive algorithms of the progression of biological time. - Develop and test the predictive model or algorithm against a blind panel to predict doubling time, cell cycle progression, metabolism and lifespan metrics. ***FY 2015 Plans:*** - Utilize predictions of cell cycle progression to demonstrate an alternative approach to biofuel production by modulating temporal processes in biofuel producing organisms. - Investigate alternative strategies for treating disease by targeting clocking systems that drive temporal processes such as cell cycle progression and metabolic cycles. - Test the ability of predictive algorithms of biological time to enable an economical and easily administered test to assess and predict human circadian phase from blood. - Expand the use of high-performance computing to help the military replace some animal and human experimentation with in-silico models of cell activity, primarily in cellular dynamics.			
Title: Quantitative Models of the Brain	5.000	10.092	12.915
Description: The Quantitative Models of the Brain program will establish a functional mathematical basis on which to build future advances in cognitive neuroscience, computing capability, and signal processing across the DoD. An important focus of this program will be determining how information is stored and recalled in the brain and other DoD-relevant signals and developing predictive, quantitative models of learning, memory, and measurement. Using this understanding, the program will develop powerful new symbolic computational capabilities for the DoD in a mathematical system that will provide the ability to understand complex and evolving signals and tasks while decreasing software and hardware requirements and other measurement resources. This includes a comprehensive mathematical theory to extract and leverage information in signals at multiple acquisition levels, which would fundamentally generalize compressive sensing for multi-dimensional sources beyond domains typically used. New insights related to signal priors, task priors, and adaptation will enable these advances. This program will further exploit advances in the understanding and modeling of brain activity and organization to improve training of individuals and teams as well as identify new therapies for cognitive rehabilitation (e.g., TBI, PTSD). Critical to success will be the ability to detect cellular and network-level changes produced in the brain during the formation of new, hierarchically organized memories and memory classes, and to correlate those changes with memory function of animals during performance of behavioral tasks.			

Exhibit R-2A, RDT&E Project Justification: PB 2015 Defense Advanced Research Projects Agency		Date: March 2014
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** BLS-01 / *BIO/INFO/MICRO SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
FY 2013 Accomplishments: - Identified fundamental bounds on performance and cost associated with linear and nonlinear signal priors. - Demonstrated novel reconstruction algorithms that incorporate both signal and task priors to enable improved reconstruction quality and/or reduced measurement resources. - Demonstrated visible imaging using 10x fewer measurements than reconstructed pixels. - Demonstrated RADAR imaging using 10x less bandwidth than a conventional non-compressive system. - Exploited the benefit of adaptation in order to achieve additional reductions in performance and/or measurement resources. - Exploited the benefit of information-optimal measurements within a signals intelligence application. ***FY 2014 Plans:*** - Demonstrate hyperspectral imaging using 100x fewer measurements than reconstructed voxels. - Explore application of compressive sensing concepts to alternate sensing modalities such as x-ray imaging. - Investigate the potential gains available from compressive sensing within a video application. - Leverage advances in neuroscience and neurological measurements to develop predictive, quantitative models of memory, learning, and neuro-physiologic recovery. ***FY 2015 Plans:*** - Quantify spatio-temporal patterns of neurochemical activity underlying memory formation. - Extend model and brain regions to account for hierarchical organization of memories (procedural, declarative/episodic). - Demonstrate model prediction of knowledge and skill-based memory encoding. - Develop model of memory encoding using non-invasively recorded neural signals.			
Title: Physics in Biology	4.572	2.947	-
Description: Understanding the fundamental physical phenomena that underlie biological processes and functions will provide new insight and unique opportunities for understanding biological properties and exploiting such phenomena. Physics in Biology will explore the role and impact of quantum effects in biological processes and systems. This includes exploiting manifestly quantum mechanical effects that exist in biological systems at room temperature to develop a revolutionary new class of robust, compact, high sensitivity and high selectivity sensors. Finally, the quantum phenomena uncovered will be exploited to control the attraction of insects to humans with the potential to completely eliminate insect bites and thus the transmission of parasitic, bacterial or viral pathogens. ***FY 2013 Accomplishments:*** - Developed prototype synthetic sensors that utilize biologically inspired quantum effects and model their performance. - Demonstrated, using radio frequency fields, that avian and insect magnetoreception is due to quantum effects through the radical pair mechanism.			

Exhibit R-2A, RDT&E Project Justification: PB 2015 Defense Advanced Research Projects Agency		Date: March 2014
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** BLS-01 / *BIO/INFO/MICRO SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Demonstrated the biological and evolutionary advantage of quantum effects in photosynthetic systems. ***FY 2014 Plans:*** - Demonstrate prototype quantum biological sensors and measure against equivalent state-of-the-art sensors in order to quantify the increase in sensitivity, selectivity and other performance metrics. - Explore quantum physics-based mechanisms of mosquito bio-sensing related to mosquito attraction to humans for novel, vector-born disease protection against diseases such as malaria or dengue fever.			
Title: Biological Adaptation, Assembly and Manufacturing ***Description:*** The Biological Adaptation, Assembly and Manufacturing program examined the structure, function, and informational basis underlying biological system adaptation, and the factors employed by the organism to assemble and manufacture complex biological subsystems. The unique stability afforded biological systems in their ability to adapt to wide extremes of physical and psychological parameters was examined and exploited in order to engineer stability into biological systems required for the military. Applications to Defense systems include the development of chemical and biological sensors; tools for strategic military decision-makers involved in information operations, and improved warfighter battlefield survivability. ***FY 2013 Accomplishments:*** - Developed sensor suite technologies based on neurobiological mechanisms to measure narrative effect on individuals/groups in real-time. - Studied generalized findings in relation to distinct sub-groups to elucidate potential differences across varying cultures. - Incorporated findings about the neurobiology of culture-dependent and culture-independent variables into models and simulations of narrative influence. - Refined sensor suite technologies.	9.496	-	-
Accomplishments/Planned Programs Subtotals	31.068	24.871	21.148

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 2015 Defense Advanced Research Projects Agency			Date: March 2014
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) CCS-02 / *MATH AND COMPUTER SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2013	FY 2014	FY 2015 Base	FY 2015 OCO #	FY 2015 Total	FY 2016	FY 2017	FY 2018	FY 2019	Cost To Complete	Total Cost
CCS-02: *MATH AND COMPUTER SCIENCES*	-	67.762	91.022	114.290	-	114.290	133.812	130.729	136.551	138.657	-	-

The FY 2015 OCO Request will be submitted at a later date.

A. Mission Description and Budget Item Justification

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

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
Title: Unconventional Processing of Signals for Intelligent Data Exploitation (UPSIDE)	10.000	15.000	22.097
Description: The Unconventional Processing of Signals for Intelligent Data Exploitation (UPSIDE) program will address the open problems facing real-time Intelligence, Surveillance and Reconnaissance (ISR) systems and other power-constrained data-intensive applications. The objective of the UPSIDE program is to create a high-level, non-Boolean computational model and map it directly to the unique functional properties of new emerging devices to achieve significant increases in power efficiency and performance. The UPSIDE program will create a new generation of computing structures that will, in turn, enable revolutionary advances in ISR processing, particularly for DoD applications of embedded, real-time sensor data analysis. Boolean data representations are inherently power-inefficient for many datasets, particularly those produced by noisy analog real-time sensors. The UPSIDE program will establish an unconventional, non-Boolean, computing paradigm to enable new and needed capabilities in the area of sensor data analysis. UPSIDE intends to implement this new computing paradigm in the form of a specialized hardware component termed the inference module (IM). The inference module will be first developed through simulation, and then implemented using mixed-signal complementary metal-oxide semiconductor (CMOS) technology, as well as using state of the art emerging (non-CMOS) devices. Throughout the program, the inference module will be benchmarked using a DoD-relevant image processing pipeline, to verify gains in both computing throughput and power efficiency. The result will be computing infrastructures and functional implementations that demonstrate three orders of magnitude improvement in processing speed and four orders of magnitude improvement in power efficiency. These gains will constitute a disruptive new level of embedded computational efficiency for future real-time sensor systems.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
FY 2013 Accomplishments: - Defined unconventional (non-Boolean) computing methodology and inference module abstraction. - Identified target recognition and tracking application. ***FY 2014 Plans:*** - Create conventional image processing pipeline simulation for baseline comparison of UPSIDE image processing metrics. - Initiate design of a mixed-signal complementary metal-oxide semiconductor (CMOS) chip-based inference module architecture. - Develop the emerging device simulations and specifications necessary to begin work on an emerging-device-based inference module. - Begin fabrication of the emerging device(s). - Begin development of CMOS support chip for emerging devices. ***FY 2015 Plans:*** - Simulate the selected image processing pipeline utilizing the previously developed inference methodology. - Develop mixed-signal CMOS based image processing pipeline simulation and validate the simulation using real-time, high-definition video streams. - Design and fabricate mixed-signal CMOS chip implementation of inference module. - Fabricate and demonstrate simple circuits based on emerging devices for future inference module development.			
Title: Young Faculty Award (YFA) ***Description:*** The goal of the Young Faculty Award (YFA) program is to encourage junior faculty at universities and their equivalent at non-profit science and technology research institutions to participate in sponsored research programs that will augment capabilities for future defense systems. This program focuses on speculative technologies for greatly enhancing microsystems technologies and defense sciences. The long-term goal for this program is to develop the next generation of scientists, engineers, and mathematicians in key disciplines who will focus a significant portion of their careers on DoD and National Security issues. Beginning in 2013, YFA technical topic areas are more closely tied to programs currently underway at DARPA and to recently identified DoD and National Security needs. The aim is for YFA recipients to receive deep interactions with DARPA program managers, programs, performers, and the user community. Current activities include research in thirteen topic areas spanning from Quantum Science and Technology to Robotics and Supervised Autonomy, Mathematics, Computing, and the Interface of Engineering and Biology. A key aspect of the YFA program is DARPA-sponsored military visits; all YFA Principal Investigators are expected to participate in one or more military site visits to help them better understand DoD needs. ***FY 2013 Accomplishments:*** - Exercised 51 second year options for FY2012 participants to continue research focused on new concepts for microsystem technologies, innovative information technologies, and defense sciences.	14.653	16.000	18.569

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Awarded 25 FY2013 grants for new two-year research efforts across the science and engineering topic areas. - Established and improved approaches to bring appropriate technologies developed through YFA to bear on relevant DoD problems and provided awardees mentorship by program managers and engagement with DARPA to encourage future work that focuses on DoD needs. - Developed important technical achievements that led to immediate commercialization efforts: (1) a portable, disposable and easy-to-operate microfluidic platform for point-of-care assessment of platelet dysfunction; and (2) a label-free high-throughput microfluidic device for the characterization of immune cell states. ***FY 2014 Plans:*** - Exercise second year options for successful FY2013 participants to continue research focused on new concepts for microsystem technologies and defense sciences. - Award FY2014 grants for new two-year research efforts across the topic areas. - Identify top FY2013 participants as candidates for selection as a Director's Fellow. During this additional year of funding researchers will refine their technology further and align to DoD needs. - Establish approaches to bring appropriate technologies developed through YFA to bear on relevant DoD problems. - Provide awardees mentorship by program managers and engagement with DARPA to encourage future work that focuses on DoD needs. ***FY 2015 Plans:*** - Award Director's Fellowships from top FY2013 participants. During this additional year of funding researchers will refine their technology further and align to DoD needs. - Exercise second year options for FY2014 participants to continue research focused on new concepts for microsystem technologies and defense sciences. - Award FY2015 grants for new two-year research efforts across the topic areas. - Establish approaches to bring appropriate technologies developed through YFA to bear on relevant DoD problems. - Provide awardees mentorship by program managers and engagement with DARPA to encourage future work that focuses on DoD needs.			
Title: Graph-theoretical Research in Algorithm Performance & Hardware for Social networks (GRAPHS)	8.251	5.213	4.903
Description: While the DoD has been extremely effective in deploying rigorous analytical and predictive methods for problems involving continuously valued variables (tracking, signals processing), analytical methods for discrete data such as graphs and networks have not kept pace. Recent evidence has shown that social network analysis can provide critical insight when used in DoD-relevant scenarios. In this paradigm, nodes represent people of interest and their relationships or interactions are edges; the result forms a network or graph. Current analysis of social networks, however, is just in its infancy: the composition of real-world networks is understood only at the most coarse and basic details (diameter, degree distribution). In order to implement			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
social network techniques efficiently and usefully, a better understanding of the finer mathematical structure of social networks is needed. This includes the development of a comprehensive and minimal mathematical set that characterizes social networks of DoD interest, and a description of how these quantities vary in both space and time. ***FY 2013 Accomplishments:*** - Derived analytic models for commonly occurring social network configurations such as call graphs. - Characterized normalcy and anomaly in structural signal constituents and formulated a detection methodology that incorporates novel noise models. - Developed Efficient Polynomial Time Approximation Schemes (EPTAS) for relevant graph algorithms. - Tested modeling and detection methods against existing text and citation networks and evaluated their effectiveness. - Developed prototype of a multi-node, customized system leveraging existing hardware that will realize at least a 10 fold performance time improvement in the current state of the art. ***FY 2014 Plans:*** - Develop mathematical models and demonstrate mechanistic methods on use cases in DoD-relevant scenarios including brain science, decision support tools for health and disease prevention and prediction, massive streaming networks, and gene networks. - Investigate and develop probabilistic graph models, statistical measures, and statistical sampling procedures for various graph models. ***FY 2015 Plans:*** - Create a suite of systematic network analysis tools that can be applied to static and dynamic network structures and complex use cases. - Develop near real-time scalable algorithms and models with guaranteed accuracy performance for inference, decision support, and understanding macro-phenomena.			
Title: Probabilistic Programming for Advancing Machine Learning (PPAML)*	-	10.221	15.671
Description: *Previously funded in PE 0602702E, Project TT-13. The Probabilistic Programming for Advancing Machine Learning (PPAML) program will create an advanced computer programming capability that greatly facilitates the construction of new machine learning applications in a wide range of domains. This capability will increase the number of people who can effectively contribute, will make experts more productive, and will enable the creation of new tactical applications that are inconceivable given today's tools. The key enabling technology is a new programming paradigm called probabilistic programming that facilitates the management of uncertain information. In this approach, developers will use the power of a modern (probabilistic) programming language to quickly build a generative			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
model of the phenomenon of interest as well as queries of interest, which a compiler will convert into an efficient application. PPAML technologies will be designed for application to a wide range of military domains including ISR exploitation, robotic and autonomous system navigation and control, weather prediction, and medical diagnostics. ***FY 2014 Plans:*** - Design and build the front end of a probabilistic programming system that enables users from a range of skill levels to construct concise but useful models. - Design and build the back end of a probabilistic programming system that takes as input expressive models written in a probabilistic programming language, queries, and prior data and produces as output an efficient implementation with predictable performance. - Identify and develop challenge problems from various military domains, including collecting and making available sample data of appropriate size. ***FY 2015 Plans:*** - Identify and develop challenge problems from various military domains with increasing levels of complexity and larger data sets. - Evaluate performance of each probabilistic programming system on each challenge problem. - Extend the front end of a probabilistic programming system with additional functionality, including profilers, debuggers, and model verification/checking tools. - Extend the back end of a probabilistic programming system with additional functionality, such as determining which solver or set of solvers is most appropriate for a given input, improving efficiency of solvers, and compiling inference engines to a range of different hardware targets.			
Title: Big Mechanism ***Description:*** The Big Mechanism program will create new approaches to automated computational intelligence applicable to diverse domains such as biology, cyber, economics, social science, and intelligence. Mastering these domains requires the capability to create abstract yet predictive - ideally causal - models from massive volumes of diverse data generated by human actors, physical sensors, and networked devices. Current modeling approaches are heavily reliant on human insight and expertise, but the complexity of these models is growing exponentially and has now, or will soon, exceed the capacity for human comprehension. Big Mechanism will create technologies to extract and normalize information for incorporation in flexible knowledge bases readily adapted to novel problem scenarios; powerful reasoning engines that can infer general rules from a collection of observations, apply general rules to specific instances, and generate (and compute the likelihood of) the most plausible explanations for a sequence of events; and knowledge synthesis techniques to derive abstract principles and/or create models of extreme complexity consistent with huge volumes of data. Big Mechanism applications will accommodate an operator-in-the-loop by accepting questions posed in human natural language; providing drill-down to reveal the basis for an answer; taking user inputs to improve/correct derived associations, weightings, and conclusions; and querying the operator to clarify ambiguities	-	7.000	15.250

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
and reconcile detected inconsistencies. Big Mechanism techniques will integrate burgeoning data into causal models and explore these models for precise interventions in critical areas such as cancer modeling, systems biology, epidemiology, cyber attribution, open-source intelligence, economic indications and warning, and human-social-cultural-behavioral modeling. This program is an outgrowth of Graph-theoretical Research in Algorithm Performance & Hardware for Social networks (GRAPHS). ***FY 2014 Plans:*** - Formulate new approaches to automated computational intelligence applicable to diverse domains. - Create technologies to extract and normalize diverse information - symbolic, qualitative, and quantitative - for incorporation in flexible knowledge bases readily adapted to novel problem scenarios. - Specialize automated computational intelligence techniques for particular applications in domains such as biology, cyber, and intelligence. ***FY 2015 Plans:*** - Develop reasoning engines that can infer general rules from a collection of observations, apply general rules to specific instances, and generate (and compute the likelihood of) the most plausible explanations for a sequence of events. - Create knowledge synthesis techniques to derive abstract principles and/or create models of extreme complexity consistent with huge volumes of data. - Develop tools for operator drill-down, ambiguity clarification, and inconsistency reconciliation. - Demonstrate automated computational intelligence techniques in one or more application domains.			
Title: Mining and Understanding Software Enclaves (MUSE) ***Description:*** The Mining and Understanding Software Enclaves (MUSE) program will develop program analyses and frameworks for improving the resilience and reliability of complex applications. MUSE techniques will apply machine learning algorithms to large software corpora to repair likely defects and vulnerabilities in existing programs and to discover new programs that conform to desired behaviors and specifications. MUSE frameworks will enable robust execution of large-scale and data-intensive computations. Specific technical challenges include persistent semantic artifact generation and analysis, defect identification and repair, pattern recognition, and specification inference and synthesis. MUSE research will improve the security of intelligence-related applications and enhance computational capabilities in areas such as graph processing, entity extraction, link analysis, high-dimensional data analysis, data/event correlation, and visualization. This program is an outgrowth of Probabilistic Programming for Advancing Machine Learning (PPAML). ***FY 2014 Plans:*** - Formulate approaches for task splitting and assignment to optimize utilization of heterogeneous computing resources. ***FY 2015 Plans:***	-	4.500	9.000

Exhibit R-2A, RDT&E Project Justification: PB 2015 Defense Advanced Research Projects Agency		Date: March 2014
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Develop data structures suitable for partitioning across distributed storage and processing infrastructure. - Develop concepts and algorithms for computational resilience and fault-recovery through a combination of fault-tolerance, fault-detection, fault-correction, and checkpointing/rollback.			
Title: Transparent Computing ***Description:*** The Transparent Computing program will develop technologies to enable the implementation of more effective security policies across distributed systems. The scale and complexity of modern information systems obscures linkages between security-related events, the result being that detection of attacks and anomalies must rely on narrow contextual information rather than full knowledge of the event's provenance. This shortcoming facilitates attacks such as masquerade (at the user level) and mimicry (at the machine code level). Conversely, the space of security policies that can be enforced under the current operating paradigm is extremely narrow and restrictive; to the extent that users and administrators are required to make security decisions based on limited information, the default is often to just click through. The Transparent Computing program will pursue several promising approaches to these problems, including active/continuous testing via cooperating defenses, where protection components propagate security-relevant information and enable on-the-fly adaptation of the system security posture and usage controls, and behavior attestation techniques that ensure component interactions are consistent with established behavior profiles without exhaustive enumeration of all acceptable program states. Transparent Computing technologies are particularly important for large integrated systems with diverse components such as distributed surveillance systems, autonomous systems, and enterprise information systems. ***FY 2015 Plans:*** - Formulate approaches for tracking information flows and recovering event provenance to enable more effective detection of attacks and anomalies such as masquerade and mimicry. - Develop active/continuous testing and adaptive security policy schemes that adjust security posture and usage controls in response to information provided by distributed protection components. - Introduce dynamic behavioral attestation techniques and propose and analyze scalable algorithms and implementations.	-	-	10.000
Title: Human and Computer Symbiosis (HCS) ***Description:*** The Human and Computer Symbiosis (HCS) program will develop technology for computers to find and use human sources of information. HCS technology will enable computers to identify when they lack necessary information, generate and send texts containing questions to identified collaborators, and integrate and learn from the replies. Because some questions can be answered only by subject matter experts, collaborators will be asked to answer a question if they can and otherwise to forward the question. Tracking these exchanges will enable the computer to learn to send questions directly to the right subject matter experts in the future. As knowledge is acquired, some computers will specialize and become subject matter experts themselves while other computers will become directories of experts that can provide guidance about where to find knowledge. When enough	-	-	10.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
computers have compiled enough knowledge, humans will start to access them by the same mechanism that the computers use: by asking questions. A major technical challenge concerns the formalism in which questions and answers are posed. Human languages will be adequate for some questions, but sometimes mathematics or pictures or other formalisms will be required. ***FY 2015 Plans:*** - Develop algorithms by which computers can determine what they need to know in a given situation. - Develop algorithms to frame knowledge needs as questions posed in natural language. - Develop algorithms to integrate human-supplied natural language answers into a knowledge base. - Develop algorithms to evaluate the quality of answers an individual provides as the basis for quantifying their value as a subject matter expert.			
Title: Full Spectrum Learning ***Description:*** This program was previously funded in PE 0602702E, TT-06. The Full Spectrum Learning (FSL) program will optimize individualized instruction and educational assessment by leveraging advances in information technology, mobile sensors, large-population datasets, neuroscience, and social emotional constructs. The tools developed under this program will provide real-time assessment of attention, comprehension, and engagement. FSL will transform training research by continuously optimizing and assessing content using population-sized datasets. The result will be the development of novel assessment metrics for future generations of computerized educational technologies and the capability to provide highly individualized instruction across large populations of users. ***FY 2015 Plans:*** - Initiate the development of a suite of tools that quantify the learning process and increase training efficacy and efficiency. - Use sensors (i.e., EEG) for recording of physiologic, environmental, and neurocognitive data. - Develop human/machine interfaces that visualize complex data and information and provide user-adapted feedback. - Create analysis tools that provide learning predictions and recommendations as output.	-	-	6.500
Title: Cortical Processor ***Description:*** Capturing complex spatial and temporal structure in high-bandwidth, noisy, ambiguous data streams to meet DoD's needs cannot be achieved even by state-of-the-art signal/image analysis systems. However, there is a processing structure in nature, the mammalian neocortex, that efficiently captures spatial and temporal structure and routinely solves the most difficult recognition problems in real-time and is a general purpose structure for a range of sensor data processing and motor control execution. The Cortical Processor program will leverage simplified models of known cortical operation to develop a new processor architecture that is optimized for running a family of algorithms known as Hierarchical Temporal Memory (HTM), providing new levels of performance and capabilities to a broad range of data recognition problems. HTM models map well to	-	-	2.300

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
simple, massively parallel, signal processor arrays, and a cortical processor leveraging advances in dense memory structures on a complementary metal-oxide semiconductor (CMOS) chip running at a few watts can perform orders of magnitude larger tasks than HTM systems simulated by commercial efforts on large data-center clusters. And with certain specialized circuits, several orders of magnitude improvement in throughput and efficiency will be possible with the cortical processor, enabling a wide range of powerful, ultra-low power, embedded applications. The Cortical Processor program includes basic scientific exploration into a variety of topics central to the development of this fundamentally new computing methodology. The ultimate goal of the Cortical Processor program is to fabricate an accelerator/ coprocessor, in silicon, that contains thousands of reconfigurable, interconnected HTM modules. HTM algorithm and data representation research will be conducted to determine optimal implementation to efficiently utilize the collective operation of the individual modules to achieve the unique features and functionality required by the cortical processor. Each of the cortical processor modules will communicate with a large subset of other nodes requiring development of dense interconnect technology and research into a variety of on-chip network optimizations for the architecture to achieve the connectivity required. Opportunities for significant improvements in power efficiency and speed will be achieved by leveraging recent advances in dense memory structures, such as multi-level floating gates, processors in memory, or 3D integration. Applied research for the program is budgeted in PE 0602303E, Project IT-02. ***FY 2015 Plans:*** - Begin development of HTM algorithm including new data representations and ability to adapt and scale. - Initiate design of memory and controller, accounting for highly interconnected memory access. - Begin research on-chip networking for communication and computation to meet required power and performance.			
Title: Strategic Social Interaction Modules (SSIM)	11.680	13.870	-
Description: The Strategic Social Interaction Modules (SSIM) program will improve military training to include the social interaction skills and abilities warfighters need for successful engagement with local populations. In the current and likely future operational environment, it is imperative to develop rapport with local leaders and civilians as their cooperation and consent will be necessary for successful operations. SSIM will emphasize the foundational social skills necessary to achieve cultural understanding in any social setting and the skills necessary for successful interactions across different social groups. These core skills do not require soldiers to have knowledge of a specific culture prior to contact but emphasizes skills for orienting toward and discovering patterns of meaningful social behavior. SSIM will develop the requisite training technology, including advanced gaming/simulation techniques, that incorporate new methods for practicing social agility in social encounters, as well as how to discover and adapt to unfamiliar culturally-specific conduct, manners, and practices. SSIM will enhance military effectiveness by enabling close collaborative relationships with local peoples and leaders.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
FY 2013 Accomplishments: - Tested accuracy of non-player-character reactions to trainees' actions and behaviors. - Developed methods to evaluate the effectiveness of SSIM-trained warfighters during interpersonal interactions with local populations. - Enhanced the video-capture and analysis of trainees' interactions during tasks that require cross-cultural interactions. ***FY 2014 Plans:*** - Refine the curriculum for SSIM-oriented training based on findings regarding effective social interaction. - Extend the assessment of the effectiveness of SSIM-training to determine direct and indirect effects. - Deploy the SSIM-based training and training simulator to transition partners. - Field-test prototypes of new training technologies.			
Title: Engage	7.078	11.815	-
Description: The Engage program develops on-line approaches for complex problem solving in real-world settings by analyzing and adapting performance across large numbers of users. Using unconventional mechanisms and incentives, Engage will create an on-line environment for data-driven, interactive, multidisciplinary collaboration among experts and non-experts to address heretofore insolvable DoD challenge problems. This big-data analysis approach will identify optimum training strategies and result in the development of software that is highly individualized to the user. Engage will also address the difficult problem of assessing performance in the virtual domain to predict performance in the real world and drive the creation of more effective on-line training. Engage technologies are being transitioned to the Department of Defense Educational Activity (DoDEA). ***FY 2013 Accomplishments:*** - Developed computational models that support learning, instruction, adaptivity, and game assessment. - Improved the problem-solving training platform based on the initial research and testing results. - Re-implemented the various application domain software components using the improved platform. - Continued analysis of methodologies using statistics based on data drawn from a large interactive environment. - Analyzed and assessed changes to existing Engage-based software when applied to different student age groups. - Partnered with DoDEA to begin transition of Engage-based software. ***FY 2014 Plans:*** - Develop and release Engage-based software for training additional topics. - Continue transition efforts to include dissemination of Engage-based software based on lessons learned from relevant DoD training activities. - Establish a collaborative, on-line, problem-solving environment that allows experts and non-experts to address complex DoD challenge problems.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Develop design and simulation tools that allow students and instructors to determine the operation of a complex electro-mechanical system. - Demonstrate the linking between design and prototyping tools that will allow for in-field manufacturing of failed components. - Demonstrate the linking of instructional design and simulation tools with rapid prototyping machines to allow for the troubleshooting and repair of failed components in electro-mechanical systems.			
Title: Mathematics of Sensing, Exploitation and Evaluation (MSEE)	11.000	4.853	-
Description: The Mathematics of Sensing, Exploitation and Evaluation (MSEE) program seeks to create a comprehensive mathematical theory of information processing, strategy formulation and decision determination. Such a theory would incorporate techniques from diverse mathematical disciplines such as Stochastic Process Theory, Harmonic Analysis, Formal Languages and Theoretical Computer Science to construct a common framework wherein the quantitative value of data acquisition may be assessed relative to dynamically-varying context. In addition, the structure will accommodate the notion that data acquisition and information processing are coupled, requiring some degree of feedback and control, while simultaneously admitting the possibility of different logics, such as those that allow for incomplete and time-varying states of knowledge. The result of this effort will produce advances in fundamental domains of mathematics with the potential to reshape current DoD approaches to managing the battlespace. ***FY 2013 Accomplishments:*** - Refined representation objects to incorporate additional capabilities, such as variable exploitation or execution tasks. - Expanded mathematical framework to allow incorporation of multiple sensing modalities, in particular, video. - Performed initial testing and validation of a prototype automated surveillance system that will be tuned to respond to events of military relevance; formulated and calculated performance metrics that quantify expected performance gains. - Designed and prototyped an algorithmic system architecture that ensures flexibility and extensibility. - Continued creation of modular open system. - Continued implementation of single-modality solution that will demonstrate effectiveness of a unified approach to sensing and will incorporate prior work on representations. ***FY 2014 Plans:*** - Implement multiple-modality solutions that will demonstrate effectiveness of a unified approach to sensing. - Create an advanced evaluation test-bed that will enable probative, quantitative assessment of a system's ability to understand scene semantics.			

Exhibit R-2A, RDT&E Project Justification: PB 2015 Defense Advanced Research Projects Agency		Date: March 2014
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Demonstrate enhanced anomaly detection under varying operating conditions, including production of a single (unified) semantic representation of a scene in the presence of coincident sensor data coming from multiple modalities, only some of which may comprise electro-optical/IR.			
Title: Computer Science Study Group (CSSG) ***Description:*** The Computer Science Study Group (CSSG) program supports emerging ideas from the computer science academic community to address the DoD's need for innovative computer and information science technologies; introduces a generation of junior researchers to the needs and priorities of the DoD; and enables the transition of those ideas and applications by promoting joint university, industry, and government projects. The CSSG project formalizes and focuses this research for efficiency and greater effectiveness. ***FY 2013 Accomplishments:*** - Transitioned successful research outcomes from Classes 2009-2011. - Awarded grants to seven principal investigators who successfully transitioned their research into partnerships with other sources of funding from government or industry. - Co-hosted social media workshop with National Geospatial Intelligence Agency (NGA) and the Department of Homeland Security (DHS). - Facilitated multiple research projects with NSA, NGA, and Army Research Laboratory (ARL). ***FY 2014 Plans:*** - Transition successful research outcomes from Classes 2010-2011.	5.100	2.550	-
Accomplishments/Planned Programs Subtotals	67.762	91.022	114.290

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 2015 Defense Advanced Research Projects Agency			Date: March 2014
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COST ($ in Millions)	Prior Years	FY 2013	FY 2014	FY 2015 Base	FY 2015 OCO #	FY 2015 Total	FY 2016	FY 2017	FY 2018	FY 2019	Cost To Complete	Total Cost
CYS-01: *CYBER SCIENCES*	-	17.095	26.333	28.627	-	28.627	28.000	12.000	12.000	8.000	-	-

The FY 2015 OCO Request will be submitted at a later date.

A. Mission Description and Budget Item Justification

The Cyber Sciences project supports long term national security requirements through scientific research and experimentation in cyber security. Networked computing systems control significant elements of critical national infrastructure, from power plants and energy distribution grids, transportation systems, food and water distribution systems, and financial networks to defense systems. During the past decade information technologies have driven the productivity gains essential to U.S. economic competitiveness. Unfortunately, during the same period, cyber adversaries, which include nation-states, criminal/terrorist groups, transnational actors, and lone miscreants, have grown rapidly in sophistication and number. The Cyber Sciences project will ensure DoD resilience in the face of adversary attempts to degrade, disrupt, or deny military computing, communications, and networking systems. Basic research in cyber security is required to provide a basis for continuing progress in this area. Promising research results will transition to both technology development and system-level projects.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
Title: Automated Program Analysis for Cybersecurity (APAC)	17.095	26.333	20.627

Description: Automated Program Analysis for Cybersecurity (APAC) is developing automated program analysis techniques for mathematically validating the security properties of mobile applications. This will involve creating new and improved type-based analysis, abstract interpretation, and flow-based analysis methods with far greater ability to accurately demonstrate security properties without false alarms than is possible today. APAC technologies will enable developers and analysts to identify mobile applications that contain hidden malicious functionality and bar those applications from DoD mobile application marketplaces.

FY 2013 Accomplishments:
- Measured the effectiveness of prototype tools and specific properties against the program metrics: false alarm rate, missed detection rate, and amount of manual effort required to certify a typical mobile application.
- Conducted competitive engagements to stress the capabilities incorporated in prototype tools.
- Created increasingly effective prototype tools and specific properties from the results of the engagements.

FY 2014 Plans:
- Improve the effectiveness of prototype tools to enable human analysts charged with curating a DoD app store to keep up with a realistic stream of incoming applications.
- Measure the improvement of analyst productivity and effectiveness through further engagements.
- Use measurements against the program metrics to identify prototype tools that are likely candidates for technology transition.

Exhibit R-2A, RDT&E Project Justification: PB 2015 Defense Advanced Research Projects Agency		Date: March 2014
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Identify potential transition partners and capture specific user operational needs. ***FY 2015 Plans:*** - Engage in experiments and pilot deployments of prototype tools with transition partners. - Refine tools in response to transition partner challenges. - Select prototype tools for transition and increase their Technology Readiness Level to meet the expectations of transition partners.			
Title: Cyber Computational Intelligence (CCI) ***Description:*** The Cyber Computational Intelligence (CCI) program will create new approaches to computational intelligence specialized to the cyber domain. In enterprise networks and Internet autonomous systems, huge volumes of event data are generated by diverse network elements, hosts, and end-point devices. These event data typically do not adhere to any standard, machine-readable format and some may even be provided as plain text warning/error messages intended for a human operator. CCI will create flexible knowledge base and data-scraping technologies to transparently ingest and normalize unstructured event data. In addition, CCI will develop advanced cyber reasoning engines that can extract and apply general rules for traffic flows and network behaviors to infer (and compute the likelihood of) the most plausible explanations for anomalous network activity. CCI technologies will facilitate the use of event data for monitoring network health, detecting zero-day attacks, optimizing network performance, maintaining network performance during a cyber attack, and reconstituting network capabilities in the aftermath of an attack. ***FY 2015 Plans:*** - Create flexible knowledge base and data-scraping technologies to transparently ingest and normalize unstructured event data generated by diverse network elements, hosts, and end-point devices. - Develop pattern recognition, anomaly detection, and machine learning techniques that generate indications and warning for zero-day attacks. - Formulate network management, control, and reconstitution as an optimization problem amenable to automated reasoning.	-	-	8.000
Accomplishments/Planned Programs Subtotals	17.095	26.333	28.627

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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E. Performance Metrics

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

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Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) ES-01 / *ELECTRONIC SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2013	FY 2014	FY 2015 Base	FY 2015 OCO #	FY 2015 Total	FY 2016	FY 2017	FY 2018	FY 2019	Cost To Complete	Total Cost
ES-01: *ELECTRONIC SCIENCES*	-	43.349	44.354	30.327	-	30.327	35.876	35.376	34.912	33.502	-	-

The FY 2015 OCO Request will be submitted at a later date.

A. Mission Description and Budget Item Justification

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

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
Title: Microscale Plasma Devices (MPD)	3.000	5.000	2.000
Description: The goal of the Microscale Plasma Devices (MPD) program is to design, develop, and characterize MPD technologies, circuits, and substrates. The MPD program will focus on development of fast, small, reliable, high carrier-density, micro-plasma switches capable of operating in extreme conditions, such as high-radiation and high-temperature environments. Specific focus will be given to methods that provide efficient generation of ions that can perform robust signal processing of radio frequency (RF) through light electromagnetic energy over a range of gas pressures. Applications for such devices are far reaching, including the construction of complete high-frequency plasma-based circuits, and microsystems with superior resistance to radiation and extreme temperature environments. It is envisaged that both two- and multi-terminal devices consisting of various architectures will be developed and optimized under the scope of this program. MPDs will be developed in various circuits and substrates to demonstrate the efficacy of different approaches. MPD-based microsystems are demonstrated in DoD applications where electronic systems must survive in extreme environments. The Basic Research part of this effort is focused on fundamental MPD research and will advance scientific knowledge based on the study of several key MPD design parameters. These parameters include ultra-high pressure and high carrier density regimes.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
MPD will focus on expanding the design space for plasma devices enabling revolutionary advances in micro-plasma device performance. It is expected that MPD will develop innovative concepts and technologies that are clearly disruptive with respect to the current state of the art in terms of speed of operation and robustness in extreme environments. Fundamental scientific knowledge derived from MPD is also expected to drive developments in commercialization of MPD technology developed and funded in PE 0602716E, Project ELT-01. ***FY 2013 Accomplishments:*** - Optimized plasma cavity environment for plasma generation at ultra-high (1-20 atm) pressures with emphasis on robust electronic switching. - Improved robustness of microscale plasma devices with carrier density exceeding 10E18 per cubic centimeter. - Continued to investigate effects of high temperature environments on plasma generation and microscale devices at temperatures exceeding 600 degrees Celsius. - Determined optimal parameters including gas pressure and mixture necessary for < 100 picosecond MPD switching speeds needed for robust survivability in high power electromagnetic fields. - Improved robustness of MPD devices operating in extreme radiation environments to improve average lifetime orders of magnitude beyond state of art radiation hardened complementary metal-oxide semiconductor (CMOS). - Demonstrated high power microwave conversion and mixing utilizing plasma as a robust, nonlinear upconversion medium. ***FY 2014 Plans:*** - Complete optimized microcavity designs achieving parameters and uniformity necessary for < 100 picosecond device switching speeds needed for robust survivability in high power electromagnetic fields. - Finalize and exploit studies of plasma in extreme environments (radiation and temperature) to demonstrate robust electronics capable of surviving in harsh environments orders of magnitude longer than current state of art silicon CMOS. - Determine feasibility of controlling infrared and light via manipulation, absorption and switching utilizing microscale plasmas. - Complete device modeling based on characterization of fabricated microscale plasma devices and provide results to circuit and microsystem integrators for use in DoD system designs. - Determine fundamental frequency, efficiency and power limitations of generating high-power microwave through terahertz (Thz) frequency signals utilizing plasma as a robust, non-linear up-conversion medium. ***FY 2015 Plans:*** - Complete investigations of the study of scaling properties for plasma devices in terms of size, density, robustness and switching speed. - Complete the optimization of devices that perform from RF through light frequencies.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Transition fundamental research findings into improved commercial modeling simulation and design tool capabilities, enabling DoD relevant applications that require survivability in extreme radiation and temperature environments.			
Title: Semiconductor Technology Advanced Research Network (STARNet)	20.000	20.000	20.000
Description: The Semiconductor Technology Advanced Research Network (STARNet) program is a government-industry partnership combining the expertise and resources from select defense, semiconductor, and information companies with those of DARPA to sponsor an external set of academic research teams that are focused on specific technology needs set by experts in industry and government. Efforts under this program will remove the roadblocks to achieving performance needed for future sensing, communication, computing, and memory applications. The program involves close collaboration between these experts and the academic base with industry providing 60% of program funding matched by 40% from DARPA. For both industrial and government participants, leveraging shared research funding for high risk, pre-competitive technology explorations for shared technical hurdles is very attractive. Research in STARNet is divided into a discovery thrust (ACCEL) and an integration thrust (NEXT) executed by virtual academic centers and focused on combining current or emerging technologies to provide new capabilities. ACCEL seeks to discover new material systems, devices, and novel computing/sensing architectures. NEXT involves projects on advanced analog and mixed signal circuitry, complex system design tools, and alternative computing architectures. As the projects in ACCEL mature, it is expected that they will replace the efforts in NEXT that are based on current standard technologies for integrated circuits. The STARNet program is unique. It creates a community where industry and government participate as co-sponsors to guide and learn from a large academic research base, with DoD shaping the goals to have direct impact on important long-range DoD problems. ***FY 2013 Accomplishments:*** - Designed "deep-learning" neural networks for machine learning applications such as database search, medical diagnosis, motion tracking, and voice and image recognition based on electron spin-based devices and circuits. Greater than 8 times power reduction relative to complementary metal oxide semiconductor (CMOS) technology is expected. - Fabricated the first prototype of a magnonic holographic memory that has potential for 1 terabyte/cm^2 storage density and data processing greater than 10^18 bits/sec/cm^2 for image processing and recognition. - Demonstrated a simple inverter circuit using extremely low voltage transistors exploiting excitons. - Developed an initial design for a cellular neural network based on tunnel field-effect transistors to significantly reduce the power consumed and increase performance of various information processing functions such as pattern recognition and motion detection. ***FY 2014 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Show proof-of-concept of novel transistor devices with extremely steep turn-on characteristics, allowing the potential for substantial reductions in operating voltage with correspondingly large reductions in power consumption of military electronics. - Work towards achieving the ultimate scalability of silicon-based computing systems with novel data-centric architectures and innovative parallelism strategies. - Satisfy rapidly increasing DoD need for information processing speed and scalability by designing new strategies using non-deterministic computing paradigms and novel nanodevices to compensate for the increasing unreliability of scaled CMOS very-large-scale integration (VLSI). - Develop an integrated, networked swarm of pervasive smart sensors and actuators to monitor and control environments such as buildings, cities and ultimately battlefield spaces. - Monitor and assess progress towards technical goals proposed by Centers, including reductions of 100 times in the power consumption of devices, 100 - 10,000 times lower energy consumption in logic switches, 10 - 100 times higher computational energy efficiency, scalability of technologies to sub-10 nanometer dimensions, development of novel computing architectures, and highly energy-efficient information processing systems inspired in the nervous system. ***FY 2015 Plans:*** - Design VLSI and analog systems based on novel steep-turn-on transistor devices for applications such as lower power imagers, pattern recognition, and scavenging self-powered electronics with 400x better energy-delay product. - Extend the scalability of silicon-based computing systems into the 2020-2030 time frame by exploring the benefits of integrating emerging nano-technologies heterogeneously into silicon-based designs. - Discover, develop, and demonstrate bio- and neuro-inspired information processing architectures that approach the efficiency of brain computation, while aligning well with emerging beyond-CMOS nanoscale fabrics. - Demonstrate components of sensor swarm applications such as building energy efficiency, health care delivery, manufacturing and agriculture, and warfighter situational awareness. - Establish stochastic information processing systems with statistical foundations to achieve 100 times more energy efficiency and robustness in emerging nanoscale functional fabrics for big-data and computationally intensive tasks.			
Title: Arrays at Commercial Timescales (ACT)	-	13.827	6.827
Description: Phased arrays are critical military subsystems with widespread applications in communications, electronic warfare and radar. The DoD relies heavily on phased arrays to maintain technological superiority in nearly every theater of conflict. The DoD cannot update these high cost specialized arrays at the pace necessary to effectively counter adversarial threats under development using commercial-of-the-shelf components that can undergo technology refresh far more frequently. The Arrays at Commercial Timescales (ACT) program will develop adaptive and standardized digital-at-every-element arrays. New advances in digital circuits at every element in an array panel will allow for ubiquitous phased array technology with heretofore unrealized spectral coverage and capabilities. This program will take a fundamental look at the role of digital arrays and how commonality			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
and aggregation can be affected by emerging capabilities. Simultaneously, this effort will focus on the development of arrays which can quickly create different unique RF personalities/capabilities on top of common digital hardware. The project will demonstrate levels of diversity in the use of the electromagnetic spectrum which are severely limited by the current approach of hand-designing the array with heavily specialized RF beamformers that are unique to each system. This program also has related applied research efforts funded under PE 0602716E, Project ELT-01. ***FY 2014 Plans:*** - Develop fundamental design techniques suited to common hardware components for phased array elements that can be seamlessly integrated into a wide range of platforms. - Develop fundamental components and sub-systems enabling common array modules, including active interference mitigation technology, analog processing or beamforming techniques, novel channelization techniques, and filter-less transceiver topologies. ***FY 2015 Plans:*** - Continue to develop fundamental technologies and techniques for enabling common array modules. - Investigate transition paths for fundamental technologies into array systems and common modules under development in the applied research portion of this project.			
Title: Micro-coolers for Focal Plane Arrays (MC-FPA) ***Description:*** The Micro-coolers for Focal Plane Arrays (MC-FPA) program will develop low size, weight, power, and cost (SWaP-C) cryogenic coolers for application in high- performance infrared (IR) cameras. It is well known that the sensitivity of an IR focal-plane array (FPA) is improved by cooling its detectors to cryogenic temperatures. The disadvantages of state-of-the-art cryo-coolers are their large size, high power and high cost. Thermoelectric (TE) coolers are relatively small, but are very power hungry. To reduce IR camera SWaP-C, innovations in cooler technology are needed. This program will exploit the Joule-Thomson (J-T) cooling principle, in a silicon-based Micro Electro-Mechanical Systems (MEMS) technology, 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. This program has related applied research efforts funded under PE 0602716E, Project ELT-01. ***FY 2014 Plans:*** - Demonstrate 10 mW heat lift and cooling below 200K. - Develop theoretical model for mixed refrigerants and cascaded designs. - Review preliminary designs for MC-FPA cold stage and compressor. - Design and demonstrate a chip-scale, J-T cold-head for a 640 x 480 extended shortwave infrared (e-SWIR, 1-2.4um cutoff) FPA with 4-6 µm unit cell size.	-	1.500	1.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Design and test a single-stage micro-cooler with an integrated piezoelectric compressor and cold-head with following metric: 30mm x 20mm x 10mm; 50 g. - Finalize design for a three stage J-T micro-cooler operating down to 195 K. ***FY 2015 Plans:*** - Finalize design for a five-stage J-T micro-cooler operating down to 150 K with 350 mW heat lift.			
Title: Diverse & Accessible Heterogeneous Integration (DAHI)	8.000	4.027	-
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) program takes this capability to the next level, ultimately offering the seamless co-integration of a variety of semiconductor devices (for example, Gallium Nitride, Indium Phosphide, Gallium Arsenide, Antimonide-Based Compound Semiconductors), micro-electromechanical (MEMS) sensors and actuators, photonic devices (e.g., lasers, photo-detectors) and thermal management structures. This capability 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. The Basic Research part of this program focused on the development of new hetero-integration processes and capabilities that, if successful, will be demonstrated in application-specific circuits and transferred into the manufacturing flow. This program has applied research efforts funded in PE 0602716E, Project ELT-01, and advanced technology development efforts funded in PE 0603739E, Project MT-15. ***FY 2013 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. - Initiated fabrication and test of heterogeneously integrated ultra-low-noise laser sources and on-chip laser radar systems. - Completed board-level prototypes of ultra-low-noise laser and optoelectronic signal sources and laser radar systems. Basic operating principles were verified, and data is being used for development of optimized systems. - Continued development of noise measurement methodology with sensitivity beyond state-of-the-art for advanced lasers and optoelectronic signal sources being developed within DAHI. ***FY 2014 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Complete development of new CMOS-compatible processes to achieve heterogeneous integration with diverse types of compound semiconductor transistors, MEMS, and non-silicon photonic devices. - Complete fabrication and test of heterogeneously integrated ultra-low-noise laser sources and on-chip laser radar systems. - Complete development of noise measurement methodology with sensitivity beyond state-of-the-art for advanced lasers and optoelectronic signal sources being developed within DAHI.			
Title: Advanced X-Ray Integrated Sources (AXIS)	8.094	-	-
Description: The objective of the Advanced X-Ray Integrated Sources (AXIS) program was to develop tunable, mono-energetic, spatially coherent X-ray sources with greatly reduced size, weight and power while dramatically increasing their electrical efficiency through application of micro-scale engineering technologies such as micro- and nano-electromechanical systems (MEMS and NEMS). Such X-ray sources enable new versatile imaging modalities based on phase contrast techniques which are 1000x more sensitive than the conventional absorption contrast imaging. Such imaging modalities should enable design verification of integrated circuits to validate trustworthiness as well as Forward Surgical Team imaging of soft tissues and vascular injuries from blunt trauma without the injection of a contrast enhancing agent. The radiation dose required for imaging will also be reduced. The Basic Research component of this effort focused on defining the fundamental science necessary for the creation of compact and highly efficient synchrotron X-ray sources. These sources may lead to future developments in the medical imaging field based on tunable X-ray wavelengths. ***FY 2013 Accomplishments:*** - Fabricated and demonstrated arrays of closely spaced electron sources with short pulse durations and low emittance for generating small charge bunches. - Fabricated and demonstrated dielectric structures (dielectric loaded waveguides) for accelerating electron bunch to relativistic energies. - Developed ultra-compact short pulse (<1 picosecond), high repetition rate and high power lasers employing saturable gain media. - Demonstrated microfabrication of permanent-magnet-based undulators for X-ray generation. - Demonstrated the utility of coded apertures for generation of phase contrast imaging.			
Title: Optical Radiation Cooling and Heating in Integrated Devices (ORCHID)	4.255	-	-
Description: Many Department of Defense (DoD) systems use micro-electromechanical systems (MEMS), including compact accelerometers and gyroscopes for inertial navigation and switches for optical communication and data routing. The performance of such devices is limited, in part, by the architecture and geometry of the sensing configuration and by thermal noise both in			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
the device and the signal recovery electronics. Advances in co-integration of micro-optical and MEMS technologies enable new hybrid opto-mechanical architectures for improved performance of MEMS devices. The ORCHID program leveraged recent successes within the field of cavity-opto-mechanics to explore the fundamental physics of opto-mechanical interactions on the micro-scale while driving technological development toward smaller and more robust devices capable of field deployment. It is envisioned that such devices will find broad application across DoD, particularly in the areas of microwave generation, force sensing, and optical communications. ***FY 2013 Accomplishments:*** - Demonstrated optical wavelength transfer in an opto-mechanical silica micro-sphere device through the opto-mechanical dark mode, which is immune to thermal noise, with 10% conversion efficiency. - Demonstrated low-noise microwave frequency synthesis using stimulated-Brillouin-scattering in a silica micro-disk. - Demonstrated quantum squeezing of light using an opto-mechanical system. Such light will be useful for surpassing the standard-quantum-limit for displacement sensing. - Demonstrated novel materials and geometries for reduced phase noise in opto-mechanical microwave oscillators.			
Accomplishments/Planned Programs Subtotals	43.349	44.354	30.327

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 2015 Defense Advanced Research Projects Agency			Date: March 2014
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COST ($ in Millions)	Prior Years	FY 2013	FY 2014	FY 2015 Base	FY 2015 OCO #	FY 2015 Total	FY 2016	FY 2017	FY 2018	FY 2019	Cost To Complete	Total Cost
MS-01: *MATERIALS SCIENCES*	-	80.326	85.819	85.527	-	85.527	75.624	87.777	82.423	85.763	-	-

The FY 2015 OCO Request will be submitted at a later date.

A. Mission Description and Budget Item Justification

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

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
Title: Nanoscale/Bio-inspired and MetaMaterials	12.380	16.205	28.417

Description: The research in this thrust area exploits advances in nano/micro-scale and bio-inspired materials, including computationally based materials science, in order to develop unique microstructures, material properties, and functionalities. This area also includes efforts to develop the underlying science for the behavior of materials whose properties have been engineered at the nano/micro-scale level, including metamaterials, digital materials, bio-inspired materials for sensing and actuation, and materials that are designed to mimic biological materials from molecular to macroscopic function. Specific examples of areas of interest include materials that can self-repair, adapt, and respond for soldier protection against chemical and biological threats and materials exhibiting a permanent electric charge (charged matter).

FY 2013 Accomplishments:
- Optimized fabrication methods for materials with architectural features necessary to exhibit predicted properties.
- Initiated experimental optimization of architectural features to demonstrate improvement of selected material properties based on sensitivity analyses and experimental characterization.
- Continued development of materials with architectural features necessary to exhibit predicted properties based on architecture-to-property computational design tools.
- Initiated research to determine extent to which properties normally coupled, can be decoupled using architecture-to-properties design methodology.
- Initiated scalability development to adapt fabrication methods to scaled production while maintaining architectural control.

FY 2014 Plans:
- Design materials with decoupled property combinations (e.g., strength/density, stiffness/thermal expansion) using architecture-to-property trade space capability.
- Demonstrate fabrication methods amenable to scaling and that permit architectural control capable of maintaining decoupled properties.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Demonstrate targeted enhancement to material properties (e.g., tailored coefficient of thermal expansion (CTE)/energy dissipation and load bearing stiffness). - Establish manufacturability and amenability to scaleup. Provide fabrication and characterization data package. - Initiate development of synthetic methods for preparing large sequence controlled polymer libraries. ***FY 2015 Plans:*** - Investigate the potential for developing compact, high-performance DoD sensors that exploit new insights regarding the physics of biological sensing and communications. - Investigate biomimetic and other emerging micro-robotic approaches to developing miniature, collaborative machines capable of performing precision assembly, disassembly, or removal of materials in highly inaccessible environments. - Identify hierarchical designs for digital materials with novel functional properties such as signal processing, image compression, mathematical operations, or pattern recognition. - Develop a method for screening non-natural polymer libraries for designed properties such as binding to target molecules. - Develop a method for sequencing non-natural polymers at low concentrations.			
Title: Fundamentals of Nanoscale and Emergent Effects and Engineered Devices	5.159	6.500	10.200
Description: The Fundamentals of Nanoscale and Emergent Effects and Engineered Devices program seeks to understand and exploit a broad range of physical properties and new physics that emerge as a result of material and/or device structure and organization at nano-scale dimensions. The insights gained from research performed under this thrust will enable new, more efficient, and powerful material and device architectures that will benefit many DoD applications including controllable photonic devices that operate over multiple wavelengths, ultra-high sensitivity magnetic sensors, high-throughput biochemical sensors for known and unknown (engineered) molecules, advanced armor, ultra-precision air and water purification systems, and advanced armor protection. Examples of physical effects that have been investigated under this thrust include absorption thermodynamics in metal-hydride systems, and correlated electron effects such as superconductivity and magnetism. This thrust has also included investigations of the phenomenology of various biological, physical, and social systems in order to abstract the common features that are responsible for their properties of self-organization, emergent behavior, and physical intelligence. Current efforts are focused on developing stabilization and scale-up methods to fabricate high-pressure crystal structures within domains not previously possible. This offers the promise to exploit the incredible properties of high-pressure phases (e.g., hardness for armor) using economically viable manufacturing approaches. ***FY 2013 Accomplishments:*** - Initiated efforts to identify and characterize metastable, high-pressure phases of gaseous and solid materials (extended solids) that have superior mechanical/functional properties.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Initiated development of synthesis techniques for producing extended solids at temperature and pressures amenable to scale up. ***FY 2014 Plans:*** - Validate computational tools against known high-pressure materials and apply to develop multistep pathways to selected extended solids. - Apply synthesis techniques to, and initiate synthesis of, intermediates projected to lead to selected extended solids. - Develop and demonstrate methods to stabilize extended solids at ambient temperatures and pressures. ***FY 2015 Plans:*** - Conduct synthesis of suites of intermediates to lead to selected extended solids. - Characterize the physical, structural, and chemical properties of intermediates synthesized. - Based on computational analysis and experimental results, design retrosynthetic pathways that are synthetically achievable for multistep reaction schemes to fabricate extended solids at reduced pressures.			
Title: Basic Photon Science	20.036	17.889	15.940
Description: The Basic Photon Science thrust is examining the fundamental science of photons, and their interactions in integrated devices, from their inherent information-carrying capability (both quantum mechanically and classically), to novel modulation techniques using not only amplitude and phase, but also orbital angular momentum. The new capabilities driven by this science will impact DoD through novel approaches to communications, signal processing, and imaging applications, in addition to better understanding the physical limits of such advancement. For example, fully exploiting the computational imaging paradigm and associated emerging technologies to yield ultra-low size, weight, and power persistent/multi-functional intelligence, surveillance, and reconnaissance systems that greatly enhance soldier awareness, capability, security, and survivability. Finally, the program will develop approaches for optical frequency division and harmonic generation for applications such as time distribution from ultrastable optical clocks, ultra-low phase noise microwaves, frequency references, and table-top sources of coherent x-rays, isolated attosecond pulses, and intense neutron sources for medical and non-medical applications. ***FY 2013 Accomplishments:*** - Demonstrated classical optical communications over a free space channel with a rate approaching 100 Terabit/s and separately demonstrated a communication system that achieved a photon information efficiency of 12 bits per received photon. - Demonstrated quantum mechanically secure communications at a secure key information rate greater than 1 Megabits/s and 6 bits per received photon. - Demonstrated high-rate single pixel photon detector with >93% efficiency and less than 1 dark count per second. - Demonstrated a novel polarization-maintaining fiber laser with 220 megahertz (MHz) repetition rate and stabilized carrier envelope offset for robust operation outside of the laboratory.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Demonstrated and characterized ultrashort-pulse photodetection to realize ultra-low phase noise microwaves at offset frequencies far from carrier, improving the noise floor by ~100 times, and outperforming or matching state-of-the-art low phase noise microwave generation at all offset frequencies. - Constructed a stand-alone, low phase noise microwave oscillator based on optical frequency division from a fiber-based optical frequency comb. - Constructed a 3-4 micron wavelength, 1-10 kilohertz (KHz) laser system with pulse energy of 10 millijoules. ***FY 2014 Plans:*** - Demonstrate quantum mechanically secure communications at a secure key information rate greater than 50 Mb/s and 5 bits per received photon. - Demonstrate a 30 gigahertz (GHz) oscillator using optical frequency division with a micro-frequency comb. - Demonstrate continuous wave operation of a monolithic solid-state laser with milliwatt average output power for integration into a rack mountable ultra-low noise microwave source. - Fabricate silicon nitride microresonators and bulk electro-optically generated frequency comb sources with multiple comb lines for pulse shaping applications including RF photonic filtering. - Design pump and seed lasers for optical parametric chirped pulse amplification for improved x-ray generation efficiency in the water window spectral region. - Demonstrate pump lasers with pulse energies of 2 joules at 800 nanometers and 1 millijoule at 1.8 micron wavelengths for efficient extreme ultraviolet and soft x-ray attosecond pulse generation. ***FY 2015 Plans:*** - Demonstrate 30 (GHz) microwave output from a silica disk microresonator-based optical frequency comb and high power photodiodes for chip-based, ultra-low phase noise microwave generation. - Demonstrate on-chip frequency comb and pulse shaping components utilizing indium phosphide based photonic integrated circuit technology and evaluate with bulk scale reference combs. - Demonstrate high flux soft x-ray production in the biologically critical water window spectral region and use this source for preliminary x-ray imaging demonstrations on the nanometer scale in the water window. - Demonstrate high efficiency-per-shot laser driven neutron production and construct increased repetition rate sample target inserter and laser amplifiers to improve overall neutron flux for radiography applications. - Demonstrate and control ultra-high intensity, long wavelength lasers, which can be used to generate high average power, high energy isolated attosecond (the timescale of electron dynamics in atoms and molecules) optical pulses.			
Title: Enabling Quantum Technologies ***Description:*** This thrust emphasizes a quantum focus on technology capabilities including significantly improved single photon sources, detectors, and associated devices useful for quantum metrology, communications, and imaging applications. It will also	18.591	23.352	30.970

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
exploit novel optical nonlinearities that can be used to combine quantum systems with classical coherent pulses to enable secure quantum communications over conventional fiber at rates compatible with commercial telecommunications. In addition, this thrust will examine other novel classes of materials and phenomena such as plasmons or Bose-Einstein Condensates (BEC) that have the potential to provide novel capabilities in the quantum regime, such as GPS-independent navigation via atom interferometry and communications, and ultrafast laser technologies. ***FY 2013 Accomplishments:*** - Demonstrated an optomechanical accelerometer with sensitivity of 10 micro-g/Hz^1/2 (10^-6 of the acceleration due to gravity per root hertz) sensitivity and 35 kHz (kilohertz) bandwidth. - Demonstrated an integrated optomechanical device for coupling optical and microwave photons. Using this device, demonstrated optical readout of microwave circuit and vice versa. - Demonstrated first atomic absorption signal in this clock which is consistent with a performance of 10^-13 fractional frequency stability at 1 second integration, a 100x improvement over current satellite GPS clocks. - Demonstrated soliton mode-locking in on-chip micro-frequency combs resulting in pulse widths of 100 femtoseconds (fs) with a 35 GHz repetition rate. - Developed and demonstrated an ytterbium lattice clock with timing stability of 3.2x 10^-16 at 1 second representing an error < 1 second over 50 billion years. ***FY 2014 Plans:*** - Demonstrate a single diamond nitrogen vacancy magnetometer with < 10 nm resolution that is compatible with imaging biological systems. - Validate the performance of a compact (< 10 liters) portable optical clock with a timing accuracy 10 times better than satellite GPS clocks. - Demonstrate prototype macroscopic quantum communications systems at secure long haul communications distances. - Demonstrate improved decoupling between secure bit rate and loss in long-haul quantum communications. - Implement macroscopic quantum communications testbed capable of simulating realistic conditions (loss, noise, and decoherence) through the modern fiber-optic telecommunications grid. ***FY 2015 Plans:*** - Achieve 3-axis opto-mechanical acceleration sensitivity <200 nano g/sqrt(Hz) over a 10 kHz bandwidth in a packaged device. - Use nitrogen vacancy magnetometer to image the magnetic fields from firing of a single neuron. - Sense functional changes of electronic spin labels in biomolecules (e.g., proteins, lipids) with high spatial and temporal resolution. - Validate optimized performance of slow-beam-optical-clock. - Integrate prototype macroscopic quantum communications system into quantum communications testbed.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Quantify performance of prototype macroscopic quantum communications system under realistic conditions (loss, noise, decoherence) and over secure long haul communications distances using quantum communications testbed.			
Title: Fundamentals of Physical Phenomena	9.991	8.873	-
Description: This thrust will obtain insights into physical aspects of natural phenomena such as magnetospheric sub-storms, fire, lightning, and geo-physical phenomena. New fundamental understandings of these phenomena will enable the ability to predict and exploit these physical processes. A major emphasis of this thrust is to provide predictive models for the interactions between plasmas and electromagnetic waves across a range of energy and length scales, and into new regimes. Specific efforts that fall under this heading are foundational studies on the initiation, propagation, and attachment of lightning, and their associated emissions; the critical factors affecting magnetospheric sub-storms; and understanding and quantifying the interaction of electromagnetic and acoustic waves with the plasma in flames. ***FY 2013 Accomplishments:*** - Conducted numerical studies of ion dynamics caused by Ultra Low Frequency (ULF) and of Very Low Frequency (VLF) wave propagation through the ionosphere inside density ducts created by artificial heating. - Experimentally attempted to produce artificial gravity waves. - Experimentally produced field-aligned currents which induced broadband ULF noises < 1 Hz. - Experimentally observed High Frequency (HF)-induced plasma structures and potentially determined relative HF power absorption for different altitudes, frequencies and geophysical conditions. - Continued experiments to quantify the impact of triggered lightning on properties of natural lightning (including the emission of gamma rays, x-rays, ultra violet (UV), visible and near-infrared (IR)/short wave IR, RF, VLF/ULF) and on the properties of upward going lightning and ionospheric phenomena (elves, sprites, whistlers, etc.). - Continued experiments to quantify the impact of tropospheric lightning (both triggered and natural) and its ionospheric components on the conductivity of the ionosphere and the resultant scattering of sub-ionospherically propagating VLF signals. - Initiated experiments to quantify the impact of compact intracloud discharges on lightning propagation as well as their potential contribution to the production of upward going lightning. ***FY 2014 Plans:*** - Experimentally define and quantify the causative mechanisms behind lightning initiation, propagation, and attachment. - Experimentally (in-situ) measure dosage of radiation emitted during the lightning process and its potential impact on aircraft and humans. - Experimentally define and quantify primary ionospheric effects associated with terrestrial lightning. - Test active control of ionospheric geomagnetic substorm evolution process.			
Title: MesoDynamical Architectures (Meso)	13.169	13.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015

Description: The Meso program exploits recently discovered physics at small scales to demonstrate transformative communication, sensing, and computing technologies for the DoD. The program is divided into four thrusts: nonlinearity and noise, coherent collective dynamics, information transduction, and coherent feedback control. In each of these thrusts, performers are focused on demonstrating specific technologies that will have significant impact on DoD capabilities. Technologies include high-performance frequency sources, transistors operating at 100 times lower power than current state-of-the-art, a hand-held biotoxin detector, and attojoule optical switches.

FY 2013 Accomplishments:

- Demonstrated low-phase-noise, temperature-and-acceleration-stable micro-electromechanical systems (MEMS)/nano-electromechanical systems (NEMS) oscillators in a compact package of 25 cubic-millimeters at 800 megahertz frequency (Nonlinearity & Noise thrust).
- Demonstrated the first (MEMS)/(NEMS) oscillator to acquire and track GPS. Meso oscillators were plugged into commercial devices and shown to reliably track GPS (Nonlinearity & Noise thrust).
- Fabricated the initial prototype of the first ever gate-tunable, topological insulator surface-state thermoelectric device (Coherent Collective Dynamics thrust).
- Optimized and integrated materials at large scale to achieve a magnetically gated, ultra-low power, ultra-high switching speed topological insulator transistor (Coherent Collective Dynamics thrust).
- Demonstrated prototype electronic biomolecular sensor with reduced operating current and increased detection capacity and resolution, successfully detecting critical levels of an important neurotoxin and discriminating among mass isotopes at the resolution of nuclear magnetic resonance techniques (Information Transduction thrust).
- Built the first generation of a novel miniature transistor exploiting piezoelectricity and piezoresistivity in materials for low-voltage, low-power operation, and successfully demonstrated operability and essential functionality (Information Transduction thrust).
- Fabricated circuits with up to four nodes exploiting strong nonlinearities in nanophotonic cavities (Coherent Feedback Control thrust).
- Completed software toolkit to simulate nanophotonic circuits incorporating coherent feedback to suppress errors and instabilities (Coherent Feedback Control thrust).

FY 2014 Plans:

- Produce high-performance frequency sources able to overcome the traditional limits in vibration stability, size, and power. Focus on meeting all of the Phase 3 metrics simultaneously on 1 device to provide a capability that will maintain performance in those situations of DoD relevance where current technologies fail (Nonlinearity and Noise thrust).
- Demonstrate programmability of ultra-low dissipation topological-insulator-based interconnect and demonstrate full complementary metal-oxide semiconductor (CMOS) integration (Coherent Collective Dynamics thrust).

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Demonstrate ultra-low power, ultra-high switching speed magnetic topological insulator transistor and optimize energy per operation to attain 1000 times better performance than that achieved in CMOS (Coherent Collective Dynamics thrust). - Optimize biomolecular sensor prototype, reducing power dissipation, lowering operating current, and incorporating capability to detect multiple toxins simultaneously. Complete miniaturization of sensor to enable a system detects multiple biomolecules in a liquid sample as simply as a standard test strip (Information Transduction thrust). - Fabricate and optimize a third generation piezoelectronic transistor scaled to 10 nanometers lateral dimension, with ON/OFF ratio > 1000, 3 times faster logic with 100 times lower power than CMOS at GHz clock speeds, and switching energies as low as 3 attojoules; develop complementary piezoelectronic transistor logic (inverters, ring oscillators, etc.) and design new complex, high fan-out logic circuits (Information Transduction thrust). - Increase the number of components in a robust nanophotonic circuit to several thousand, reduce their time and energy to switch to one nanosecond and 10 attojoules, and increase the level of suppression of errors by an order of magnitude for maximum reliability (Coherence Feedback Control thrust).			
Title: Atomic Scale Materials and Devices ***Description:*** This thrust examined the fundamental physics of materials at the atomic scale in order to develop new devices and capabilities. New materials and prototype devices were developed to demonstrate a new class of optoelectronics that operate with ultra-low energy dissipation (~100 atom-Joules (aJ)/operation). This class of opto-electronics is enabled by the optical Zeno effect, a counter-intuitive phenomenon whereby an increase in device absorptivity can lead to a decrease in loss. ***FY 2013 Accomplishments:*** - Demonstrated coherent, reversible switching with quantum dot spin in a cavity. - Improved switching speed to 11 picoseconds.	1.000	-	-
Accomplishments/Planned Programs Subtotals	80.326	85.819	85.527

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 2013	FY 2014	FY 2015 Base	FY 2015 OCO #	FY 2015 Total	FY 2016	FY 2017	FY 2018	FY 2019	Cost To Complete	Total Cost
TRS-01: *TRANSFORMATIVE SCIENCES*	-	34.150	42.634	32.227	-	32.227	33.361	59.900	61.613	63.000	-	-

The FY 2015 OCO Request will be submitted at a later date.

A. Mission Description and Budget Item Justification

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

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
Title: Social Media in Strategic Communication (SMISC)	14.720	20.161	7.066

Description: The Social Media in Strategic Communication (SMISC) program will develop techniques to detect, classify, measure, and track the formation, development, and spread of ideas and concepts (memes) in social media. This will provide warfighters and intelligence analysts with indications and warnings of adversary efforts to propagate purposefully deceptive messaging and misinformation. Social media creates vulnerabilities that can be exploited to threaten national security and has become a key operating environment for a broad range of extremists. SMISC will develop technology and a new supporting foundational science of social networks that will enable warfighters to defend against malevolent use of social media and to counter extremist influence operations.

FY 2013 Accomplishments:
- Refined topic modeling techniques to accurately represent tactically significant content.
- Developed specialized algorithms to recognize purposeful or deceptive messaging and misinformation, persuasion campaigns, and influence operations across social media.
- Applied information theoretic concepts to develop novel approaches for detecting hidden influence mechanisms in social media via information transfer and Granger causality.
- Designed a game theoretic model of optimal and fair allocation of social capital among nodes in networks and used the model to develop an influencer estimation algorithm.

FY 2014 Plans:
- Refine algorithms for real-time detection and tracking of memes at scale.
- Improve specialized algorithms to recognize purposeful or deceptive messaging and misinformation, persuasion campaigns, and influence operations across social media.

Exhibit R-2A, RDT&E Project Justification: PB 2015 Defense Advanced Research Projects Agency		Date: March 2014
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** TRS-01 / *TRANSFORMATIVE SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Design algorithms to identify the minimum set of sensors for a given social system based on models used to predict the social dynamics stability distribution and impact on link characteristics. - Design scalable, efficient, and accurate social malware detection algorithms. - Demonstrate methods for countering adversary influence operations using techniques of semi-automated narrative creation based on predictive social dynamics models. - Extend algorithms developed for text-centric social media and micro-blogging to new social multi-media platforms. ***FY 2015 Plans:*** - Integrate algorithms for meme detection and tracking with algorithms for detecting deception, persuasion, and influence operations. - Develop high fidelity diffusion models for messages, narratives, and information across social media. - Combine integrated algorithms with diffusion models to create predictive simulations for the spread of given messages, narratives, and information.			
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 facilitate new solutions and enhancements to military needs and capabilities. Ultimately, Living Foundries aims to provide game-changing manufacturing paradigms for the DoD, enabling distributed, adaptable, on-demand production of critical and high-value materials, devices and capabilities in the field or on base. Such a capability will decrease the DoD's dependence on tenuous material supply chains that are vulnerable to political change, targeted attack, or environmental accident. If successful, Living Foundries will do for biology what very-large-scale integration (VLSI) did for the semiconductor device industry: enable the design and engineering of increasingly complex systems to address and enhance military needs and capabilities. Living Foundries will develop and apply an engineering framework to biology that decouples biological design from fabrication, develops and yields design rules and tools, and manages biological complexity through simplification, abstraction,	9.941	10.973	11.464

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015

and standardization of both processes and components. The result will be rapid design, construction, implementation and testing of complex, higher-order genetic networks with programmable functionality and DoD applicability. Research thrusts include developing the fundamental tools, capabilities and methodologies to accelerate the biological design-build-test cycle, thereby reducing the extensive cost and time it takes to engineer new systems and expanding the complexity and accuracy of designs that can be built. Specific tools and capabilities include: interoperable tools for design and modeling; automated, modular and standardized fabrication and genome-scale engineering processes; modular regulatory elements, devices and circuits for hierarchical and scalable engineering; standardized test platforms and chassis; and novel approaches to process measurement, validation, and debugging. Applied research for this program is budgeted in PE 0602715E, Project MBT-02.

FY 2013 Accomplishments:

- Researched and developed standardized test platforms and chassis for quantitative modeling studies to predict platform behavior.
- Developed a software tool for facile annotation and design of new biosynthesis pathways and chassis resulting in a 30x compression of design time (from 1 month to 1 day).
- Developed a new method that decreased DNA design quality control costs by >23X.
- Developed a new large-scale DNA assembly method that can accurately assemble up to 20 pieces of DNA in vitro (previous state of the art was 10) and decreased the failure rate by >4X.
- Began initial experiments to design and test new production pathways for novel materials.
- Developed a software tool that identifies all feasible biosynthetic pathways to a desired product.
- Continued development of device and circuit designs and topologies that are orthogonal to and portable across multiple host chassis. This approach produces minimal cross-talk due to the ability to predict design behavior a priori.
- Began designing, constructing, modeling, and evaluating large scale, hierarchical genetic networks to demonstrate ability to forward engineer bioproduction pathways and functions.
- Initiated studies to research and develop real-time feedback and control mechanisms and tools for more complex and robust experimental design. This work may also enable enhanced control of engineered circuits and networks.
- Continued research, development, and testing of new characterization and debugging tools for synthetic regulatory networks.

FY 2014 Plans:

- Begin research and development on incorporation of new, non-natural components into bio-manufactured materials (including non-natural amino acids and an expanded set of atomic elements) to broaden the set of new materials and functions.
- Begin initial demonstration of automated, genome-scale cellular engineering process platforms that simultaneously increase the scale and complexity of experimentation and decrease the cost and time to engineer a new production system.
- Continue research and development of tools and methodologies to program, reprogram, and enable spatio-temporal control and feedback for engineered systems.

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Continue to design and assess production pathways for novel materials. - Develop novel algorithms and software that link the design of genetic systems to their assembly and characterization data to begin integrating the design of systems with their construction and ultimate testing/debugging. - Begin development and demonstration of tools to enable engineering of currently intractable chassis for novel and enhanced functionalities and materials production. ***FY 2015 Plans:*** - Examine design tool innovations to enable forward engineering of novel genetic systems. - Investigate design evaluation tools to enable massively parallel testing, validation, and verification of engineered systems. - Continue development of automated and scalable, large-scale DNA assembly and editing tools and processes. - Research new methods for integrated feedback to exploit high volume data generation and inform future designs and processes.			
Title: Open Manufacturing	9.489	8.000	3.197
Description: The Open Manufacturing program will reduce barriers to manufacturing innovation, speed, and affordability of materials, components, and structures. This will be achieved by investing in technologies to enable affordable, rapid, adaptable, and energy-efficient manufacturing and to promote comprehensive design, simulation and performance-prediction tools, and exposure to best practices. The applied research component of this program is funded in PE 0602715E, Project MBT-01 under Materials Processing and Manufacturing. ***FY 2013 Accomplishments:*** - Established tools that capture the impact of manufacturing practice and non-linear interactions between components and subsystems and that incorporate parametric and declarative attributes. - Established models that incorporate uncertainty, and develop ways to chain models together, with uncertainty embedded in each stage, to predict and guarantee that the range of performance lies within required boundaries. - Developed new testing methodologies and protocols that support rapid qualification of products. - Demonstrated methods for testing and qualification of new manufacturing technologies using impartial manufacturing centers of expertise. - Performed virtual manufacturing system exercises that pass design, manufacture, and verification of a specific part through the entire chain. ***FY 2014 Plans:*** - Develop a fundamental understanding of the impact on quality features and parameters to establish process windows for new rapid process technologies.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Develop metrology methods to support probabilistic process modeling in metals additive manufacturing and bonded composite processing. - Develop a fundamental understanding of the interaction between electromagnetic fields and refractory metals and metal matrix composites based on particle size and material. ***FY 2015 Plans:*** - Develop basic architecture and statistical environment to enable rapid qualification and certification approaches through the interaction and use of probabilistic models for process, design, and materials. - Demonstrate Micro-Induction Sintering (MIS) method for additive manufacture of metal and/or ceramic materials in complex geometries. - Demonstrate approach to verifying, validating, and quantifying uncertainty in the developed rapid qualification frameworks.			
Title: Vanishing Programmable Resources (VAPR) ***Description:*** The Vanishing Programmable Resources (VAPR) program will create electronic 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, materiel), environmental monitoring over large areas, and simplified diagnosis, treatment, and health monitoring in the field. VAPR will 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. A basis set of transient materials and electronic components with sufficient electronic and transience performance is needed to realize transient electronic systems for environmental sensing and biomedical applications. Research and development of novel materials for implementing basic transient electronic components (actives and passives), power supply strategies, substrates and encapsulants as well as development of modes and triggers for transience will form the core of fundamental research activities. Transient components and devices developed in this technical area will form the basis for advanced functional circuit blocks and test systems to be developed in PE 0602716E, Project ELT-01. ***FY 2014 Plans:*** - Establish and characterize transience of alternative semiconductors and other electronic materials for device components. - Begin developing multiple transience mechanisms, including demonstrating mechanically, electrically, and optically triggered transience.	-	3.500	2.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2013	FY 2014	FY 2015
- Begin developing electronic materials that exhibit a useful combination of transience and the necessary physical characteristics required for sufficient electronic performance. - Develop materials and mechanisms for control of transience effects. - Develop device modeling tools that incorporate transience effects. - Initiate the systematic study of novel transient packaging materials. ***FY 2015 Plans:*** - Establish electronic materials that exhibit a useful combination of transience and the necessary physical characteristics required for sufficient electronic performance. - Enhance device modeling tools that incorporate transience effects.			
Title: ACE (Advanced Capabilities in Engineering Biology) ***Description:*** The Advanced Capabilities in Engineering Biology (ACE) Program will leverage newly developed technologies for engineering biology towards enabling radical new approaches to solving National Security challenges. Engineering biology is emerging as a new field focused on developing the tools to harness the powerful synthetic and functional capabilities of biology. These tools will facilitate design and biological production of new chemicals and materials, sensing capabilities, therapeutics, and numerous other applications. This rapidly developing technological capability opens the door to new national security applications that have heretofore been out of reach, and offers substantial potential advantages in terms of cost and novel functionality. The ACE program will position the U.S. to be first in exploiting the powerful functional capabilities and applications that arise through being able to harness biological systems. A major impediment to engineering biology is that engineered organisms are often less fit than their precursors and are likely to be outcompeted by other organisms. Fundamental work in this area will focus on engineering biological robustness to ensure that engineered organisms perform as designed over the long-term. Research in this area may include developing methods to ensure genetic integrity of organisms, as well as engineering communities of microorganisms to perform useful tasks, ranging from the production of chemicals to the development of stable microbiomes to prevent and treat disease. . ***FY 2015 Plans:*** - Investigate methods to engineer organisms that do not suffer from substantially reduced fitness. - Investigate methods to engineer communities of microorganisms with tunable population dynamics. - Explore methods to rationally reengineer complex microbiomes.	-	-	8.000
Accomplishments/Planned Programs Subtotals	34.150	42.634	32.227

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C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

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