Exhibit R-2, PB 2010 Defense Advanced Research Projects Agency RDT&E Budget Item Justification									DATE: May 2009	
APPROPRIATION/BUDGET ACTIVITY 0400 - Research, Development, Test & Evaluation, Defense-Wide/BA 1 - Basic Research					R-1 ITEM NOMENCLATURE PE 0601101E DEFENSE RESEARCH SCIENCES					
COST ($ in Millions)	**FY 2008 Actual**	**FY 2009 Estimate**	**FY 2010 Estimate**	**FY 2011 Estimate**	**FY 2012 Estimate**	**FY 2013 Estimate**	**FY 2014 Estimate**	**FY 2015 Estimate**	**Cost To Complete**	**Total Cost**
Total Program Element	168.005	202.487	226.125						Continuing	Continuing
BLS-01: BIO/INFO/MICRO SCIENCES	43.317	53.027	53.825						Continuing	Continuing
CCS-02: MATH AND COMPUTER SCIENCES	23.109	38.634	50.678						Continuing	Continuing
ES-01: ELECTRONIC SCIENCES	59.105	60.145	68.860						Continuing	Continuing
MS-01: MATERIALS SCIENCES	42.474	50.681	52.762						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) 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.

(U) 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 organisms' levels.

(U) 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 to exploit computer capabilities; enhance human-to-computer and computer-to-computer interaction technologies; advance innovative computer architectures; and discover new learning mechanisms and innovations in software composition. It is also fostering the computer science academic community to address the DoD's need for innovative computer and information science technologies. Additionally, this project explores the science of mathematics for potential defense applications.

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(U) 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.

(U) The Materials Sciences project is concerned with the development of: high power density/high energy density mobile and portable power sources; processing and design approaches for nanoscale and/or bimolecular materials, interfaces and microsystems; materials and measurements for molecular-scale electronics and spin-dependent materials and devices.

B. Program Change Summary ($ in Millions)

	FY 2008	FY 2009	FY 2010	FY 2011
Previous President's Budget	174.996	195.657	226.125	
Current BES/President's Budget	168.005	202.487	226.125	
Total Adjustments	-6.991	6.830	0.000	
Congressional Program Reductions	0.000	-4.550		
Congressional Rescissions	0.000	0.000		
Total Congressional Increases	0.000	11.380		
Total Reprogrammings	-2.200	0.000		
SBIR/STTR Transfer	-4.791	0.000		

Congressional Increase Details ($ in Millions)	FY 2008	FY 2009
Project: BLS-01, **American Museum of Natural History - Infectious Disease**	0.000	2.000
Project: BLS-01, **Bio-Butanol Production Research**	0.000	2.000
Project: CCS-02, **Institute for Information Security**	0.000	2.500
Project: ES-01, **Ultra Photonics Program**	0.000	1.280
Project: MS-01, **Advanced Materials Research Institute**	0.000	2.400
Project: MS-01, **Institute for Collaborative Sciences Research**	0.000	1.200

Change Summary Explanation

FY 2008

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Decrease reflects transfer of the Alternative Futures at the Range Complex congressional add to the O&M, Defense-Wide account, the Nanocrystal Source Display congressional add to the RDT&E Army account, and the SBIR/STTR transfer.

FY 2009
Increase reflects reductions for Section 8101 Economic Assumptions offset by congressional adds (as identified above) and congressional reductions.

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COST ($ in Millions)	**FY 2008 Actual**	**FY 2009 Estimate**	**FY 2010 Estimate**	**FY 2011 Estimate**	**FY 2012 Estimate**	**FY 2013 Estimate**	**FY 2014 Estimate**	**FY 2015 Estimate**	**Cost To Complete**	**Total Cost**
BLS-01: BIO/INFO/MICRO SCIENCES	43.317	53.027	53.825						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) 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, 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. This project is also providing the supporting basic research for the effort to revolutionize prosthetics.

B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
Bio Interfaces	6.000	6.000	3.000	
(U) The Bio Interfaces program will support 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 the advances in the complex modeling of physical phenomena such as Electro-Magnetic Pulse (EMP). It is also expected that understanding the fundamentals of biology will aid in developing tools to understand complex, non-linear networks and force structures. *FY 2008 Accomplishments:* - Developed new mathematical algorithms which strengthened the metagenomics approach to ecology using population genetics and the analysis of evolving populations. - Developed a mathematical theory for the occurrence of quantum mechanical structure in biology through horizontal gene transfer and recombination. - Developed new mathematical methods targeting complexity and variability in biological systems.				

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
FY 2009 Plans: - Test and verify theoretical mathematical formulations of the laws of biology on simple systems. - Compare gene regulatory modules involved in the growth and development of plants and animals for similar functionality. - Test and verify proposed mathematical theory of collective decision making in viruses. *FY 2010 Plans:* - Test and verify theoretical mathematical formulations of the laws of biology on multi-scale systems. - Complete development of a generalized thermodynamic formalism for biological systems. - Develop theoretical mathematical formulation for rewiring of modules in regulatory pathways in bacterial evolution.					
Preventing Violent Explosive Neurologic Trauma (PREVENT)* *Previously funded under Bio Interfaces. (U) The Preventing Violent Explosive Neurologic Trauma (PREVENT) program seeks to understand the causes of blast-induced traumatic brain injury, an injury that while previously described in the warfighter population, has been referred to as a potential “hidden epidemic” in the current conflict. PREVENT will use a variety of modeling techniques based on the in-theater conditions to assess the potential traumatic brain injury caused by blast in the absence of penetrating injury or concussion. Research will create a model that can be directly correlated to the epidemiology and etiology of injury seen in returning warfighters, and attempt to determine the physical and physiological underpinnings and causes of the injury. Mitigation and treatment strategies will be formulated based on our new knowledge of blast-induced brain injury with the eventual goal of reducing injury severity across the forces by over fifty percent, improving recovery time, and preventing future injuries. *FY 2008 Accomplishments:* - Determined primary physical factors accounting for explosive-induced traumatic brain injury in experimental models.		1.960	7.000	10.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Completed epidemiological study of factors associated with explosive traumatic brain injury in warfighters. *FY 2009 Plans:* - Create protection and mitigation strategies that greatly reduce the number and extent of traumatic brain injuries in warfighter population due to explosion. - Continue studies on blast effects as needed to determine underlying physiological causes of blast induced brain injury. - Verify causes of blast brain injury through observations in warfighter population. - Assess injurious role of electrical discharge from detonation of cased munitions on central nervous system. *FY 2010 Plans:* - Refine protection and mitigation strategies and transition for use in theater and by military medical Services. - Assess the effect of commonly available pharmaceuticals in both acute and chronic mitigation of blast brain injury symptoms. - Validate diagnostic criteria for assessment of mild to severe blast brain injury. - Test and validate fabricated device strategies to ensure that they appropriately mitigate the effects of blast brain injury. - Develop devices and diagnostic platforms for blast brain injury in theater as needed.				
Biological Adaptation, Assembly and Manufacturing (U) The Biological Adaptation, Assembly and Manufacturing program will examine the structure, function, and informational basis underlying biological system adaptation, particularly to harsh environments, 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 endurance (e.g., heat, cold, and sleeplessness) parameters will be examined and exploited in order to engineer stability into biological systems required for the military (such as blood, bioengineered tissues or other therapeutics). A key new antibody technology will develop the ideal antibody master molecule	13.175	14.127	13.325	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
that maintains high temperature stability and controllable affinity for threat agents. In addition, the fault tolerance present in biological systems will be exploited in order to assemble and manufacture complex physical and multi-functional systems, both biological and abiotic (such as tissue constructs designed for reconstructive surgery). These systems include novel load-bearing bio-interactive materials and composites for repair of severe hard tissue trauma, including complex bone fractures. Further activity in this area will investigate the adaptability of the brain to information processing and situational awareness. Applications to Defense systems include the development of chemical and biological sensors, and improved battlefield survivability of the warfighter. *FY 2008 Accomplishments:* - Decreased fibrotic collagen synthesis at a wound by twenty percent in an experimental model. - Developed strategies for production of ten red blood cell units per week for four weeks in an automated closed culture system using a non-renewing (replaceable) progenitor cell population. - Developed components for mathematical model for fracture putty/bone biomechanics. - Formulated chemistry for novel resorbable wet adhesives with the mechanical properties of natural bone, for inclusion into fracture putty formulation. - Formulated components for fracture putty which approximates the mechanical properties and internal structure of natural bone. *FY 2009 Plans:* - Begin demonstration of ten blood cell units per week for four weeks in an automated closed culture system using a non-renewing (replaceable) progenitor cell population. - Enhance or produce artificial cell membranes to control, repair and improve cellular processes in the warfighter. - Demonstrate in vitro construction of multicellular tissue using one or more non-contact cell positioning approaches. - Develop complete mathematical model for fracture putty/bone biomechanics. - Develop novel resorbable wet adhesives with the mechanical properties of natural bone, for inclusion into fracture putty formulation.				

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Develop fracture putty which approximates the mechanical properties and internal structure of natural bone. - Demonstrate mechanical properties of fracture putty for in vitro model of bone fracture. - Develop a functionalized abiotic “patch” to integrate into a cell membrane to direct cell control. - Demonstrate integration of pigment melanocytes into engineered skin. - Develop engineered fat tissue positive for expression of adipocyte-specific biomarkers lipase and fatty acid-binding protein. - Demonstrate multilayer construction of engineered fat constructs. *FY 2010 Plans:* - Develop a controlled permeability pore for selective delivery of agents to the cell interior. - Enhance or produce artificial cell membranes to repair, restore, and enhance cellular processes in the warfighter. - Demonstrate degradation of fracture putty into harmless resorbable by-products. - Demonstrate compatibility of fracture putty with existing osteoinductive formulations. - Demonstrate fracture putty in both small and large animal models of bone fracture. - Formulate protocols for expanded large animal studies of fracture putty. - Demonstrate antibody stability capability at 60 degrees centigrade and select for antibody affinity with a binding constant (KD = dissociation constant) greater than 10 to the eighth.					
Nanostructure in Biology (U) The Nanostructure in Biology program will investigate the nanostructure properties of biological materials to better understand their behavior and accelerate their exploitation for Defense applications. This new information about biomolecules and complex cellular systems will provide important new leads for the development of threat countermeasures, biomolecular probes and motors, and neuromorphic sensory systems. This program will also develop approaches to mathematically predict a priori, the structure of biological materials, especially proteins, based on the desired performance. This will enable the rapid design of new biosensors against previously unknown threats and the design of advanced catalysts based on biological activity to produce new materials of interest to DoD (e.g., tailored explosives). The program will also create technology to reliably integrate nanoscale and microsystems payloads on		10.250	10.500	8.500	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
insects that will extract power, control locomotion, and also carry DoD relevant sensors. In addition, research will be conducted in the interaction, at the nanoscale, of biotic and abiotic materials and functions, a critical aspect in the development of advanced prosthetics. *FY 2008 Accomplishments:* - Constructed an in vivo map of the feature sensitivity of populations of primary visual cortical neurons using nanochannel glass recordings and two-photon microscopy techniques. - Investigated how object representation in the mammalian inferotemporal cortex is computed from downstream visual system (V4) inputs using tools from topology, geometry, and statistics. - Demonstrated autonomous locomotion control via RF control for an un-tethered cyborg. - Designed three enzymes with catalytic activity greater than 105 for known chemistries. - Designed two protein-protein binding pairs including new support scaffolds. *FY 2009 Plans:* - Create a functional model of portions of the mammalian object recognition pathway that is biologically valid and suitable for translation to algorithm development. - Optimize Micro Electro Mechanical Systems (MEMS) components for locomotion control, communications and power generation to consume less power and to reduce size, weight and cost. - Apply protein design methodology to perform region-specific nitration chemistry. - Develop a protein that inhibits the activity of influenza by preferential binding. *FY 2010 Plans:* - Discover methods for precise flight control use in combinations of MEMS techniques originating in the previous fiscal year. - Develop neural interfaces to insect sensors to compliment electronic sensors. - Extend catalytic activity of de novo designed enzymes to one billion for known chemistries. - Develop de novo protein countermeasure to degrade oximes.				
Human Assisted Neural Devices	10.332	10.900	12.500	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011

(U) The Human Assisted Neural Devices program will develop the scientific foundation for understanding the language of the brain for application to a variety of emerging DoD challenges, including improving performance on the battlefield and returning active duty military to their units. This will require an understanding of neuroscience, significant computational efforts, and new material design and implementation. Key advances expected from this research include the ability to improve decision making in a variety of DoD applications including imagery analysis. In addition, this thrust will provide an understanding of how the brain adapts as it learns. This understanding will be translated into improved training approaches that allow transition from novices to expert in military tasks such as marksmanship to be accomplished with minimum effort and time.

FY 2008 Accomplishments:

- Identified the specific brain networks and regions involved in the generation of expert performance; tracked and classified progression from novice to expert level using functional neuroimaging techniques.
- Described the progression from novice to expert level using functional neuroimaging techniques.
- Investigated non-invasive interventions to increase the speed of expertise development including neurophsyiologically-driven training regimens, neurally optimized stimuli, and stimulatory/modulatory interventions.
- Analyzed how the brain encodes and responds to vibratory tactile stimuli in order to improve neural prosthetic devices.
- Developed an artificial interface between an external vibratory sensor and the neural processes used to identify and respond to vibratory sensation.
- Decoded intended motor signal from primates in a reaching and grasping task, resulting in movement of robotic wrist and hand.
- Improved upon existing algorithmic techniques of decoding neural function in order to do work through robotic devices, resulting in incremental gains in speed and accuracy.

FY 2009 Plans:

- Optimize non-invasive neuroscience interventions that will result in a two-fold increase in the speed of expected development and dramatically accelerate the transition from novice to expert in key military tasks.

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Explore the extrapolation of task specific acceleration techniques from limited domains to wider, more general training applications. - Develop both task-specific and task-independent methods and strategies for neurophysiology-based learning acceleration applicable across multiple domains. - Identify memory neural codes that are specific to critical work related tasks, enabling possible potential memory restoration in a brain-wounded warfighter. - Verify that neural codes for short-term matching task among rodents are similar. - Create an interface that enables performance of a complex motor/sensory task through an assistive device without using either motor or sensory function. - Map dynamic functional motor and sensory networks and develop methods for characterizing brain-wide sensory/motor tasks. *FY 2010 Plans:* - Demonstrate learning acceleration techniques feasible for use across a broad range of individuals and explore the potential for group/team learning paradigms for increased quantity of expertise production. - Attempt to identify neural processes for encoding short and long-term memory in primates during a complex motor task. - Build hardware and software to implement pattern extraction and inter-individual verification of homogeneity of patterns between primates. - Determine task performance changes resulting from learning and plasticity through observation of the development of functional networks in the primate and rodent brain over time. - Construct algorithms and methods capable of more accurately describing and estimating neural signals from limited data.				
Mathematics of the Brain (MoB)* * Previously funded under Human Assisted Neural Devices (U) The Mathematics of the Brain program will develop a powerful new mathematical paradigm for understanding how to model reasoning processes for application to a variety of emerging DoD challenges. This will require constructing a novel mathematical architecture for a biologically consistent model of	0.000	2.500	2.500	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
thought that moves beyond the state of the art to allow the ability to learn and reason. The program will also develop powerful new symbolic computational capabilities for the DoD in a mathematical system that provides the ability to understand complex and evolving tasks without exponentially increasing software and hardware requirements. Finally, this program will establish a functional mathematical basis on which to build future advances in cognitive neuroscience and computing capabilities across the DoD. *FY 2009 Plans:* - Leverage recent advances in neuroscience and mathematics to construct an integrated mathematical model of the brain that is consistent and predictive, rather than merely biologically inspired. - Develop a theory that overcomes the difficulties present in traditional approaches, such as artificial intelligence and artificial neural networks. Theory should be: biologically-consistent, generalizable, scalable, dynamic and not dependent on computer based data transfer techniques. *FY 2010 Plans:* - Validate models developed from new theories for functional consistency with brain performance including learning, memory (both long term and associative), recall and simultaneous task/process execution. - Implement these mathematical theories into hardware and demonstrate consistent performance on predetermined brain functions.				
Silent Talk (U) Silent Talk will allow user-to-user communication on the battlefield without the use of vocalized speech through analysis of neural signals. The brain generates word-specific signals prior to sending electrical impulses to the vocal cords. These signals of “intended speech” will be analyzed and translated into distinct words, allowing covert person-to-person communication. This program has three major goals: a) to attempt to identify electroencephalography patterns unique to individual words, b) ensure that those patterns are generalizable across users in order to prevent extensive device training, and c) construct a fieldable pre-prototype that would decode the signal and transmit over a limited range.	0.000	0.000	4.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
FY 2010 Plans: - Identify electroencephalography (EEG) patterns unique to a subset of 100 words commonly used by the warfighter community.				
Bacterial Ghost Influenza Vaccine Development *FY 2008 Accomplishments:* - Continued development of novel genetically inactivated bacterial-based vaccines to overcome disadvantages of egg-based vaccines.	1.600	0.000	0.000	
Bio Butanol Production Research *FY 2009 Plans:* - Investigate bio-butanol production capabilities.	0.000	2.000	0.000	

C. Other Program Funding Summary ($ in Millions)

N/A

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)	FY 2008 Actual	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
CCS-02: MATH AND COMPUTER SCIENCES	23.109	38.634	50.678						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) 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; practical, logical and heuristic 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; and new learning mechanisms for systematically upgrading and improving these capabilities. Additionally, this project explores mathematical programs and their potential for defense applications. Promising techniques will transition to both technology development and system-level projects.

B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
Foundational Computer Science	15.173	8.994	12.778	
*Formerly Computer Exploitation and Human Collaboration. (U) The Foundational Computer Science program supports research in broad areas of computational science having the potential for revolutionary advances in performance and other relevant metrics above and beyond extrapolations of current approaches. The research will yield significant advances in networking, software, hardware, and computational systems that will allow warfighters and commanders of the future to interact in a natural way with computers, enable a new generation of collaboration methods and information acquisition, and provide intelligent seamless exchange of information in a world where computing devices are ubiquitous and heterogeneous. The Foundational Computer Science program is also addressing the need for highly reliable and trustworthy mission-critical information systems. Scalable formal methods and other techniques will be used to guarantee the reliability and robustness of a design while also developing techniques to reduce the complexity and cost. (U) The Information Theory for Wireless Mobile Ad Hoc Networks (ITMANET) effort is creating an information theory for ad hoc mobile wireless networking in the absence of wired infrastructure. Issues				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011

being addressed include quantifying network performance in terms of throughput, delay, reliability, and other critical parameters as a function of node mobility, network topology, channel access protocol, bandwidth efficiency, and the overhead incurred through the exchange of channel and network state information. The revolutionary new and powerful information theory developed under ITMANET will enable the next generation of DoD wireless networks and provide insight concerning the acquisition and deployment of nearer-term systems.

(U) The Foundational Computer Science program is also supporting research on the foundations of artificial intelligence: machine learning and reasoning. For machine learning, the focus is on techniques that can efficiently process and "understand" massive data streams. These will have far-reaching military implications with potential applications such as anomaly detection, object recognition, language understanding, information retrieval, pattern recognition, robotic task learning and automatic metadata extraction from video streams, sensor data, and multi-media objects.

(U) For machine reasoning, the Foundational Computer Science program is addressing problems that are inherently computationally complex and, in many cases, intractable. The game of Go provides an ideal platform for creating the heuristic approaches and tools necessary to enable effective, practical machine reasoning about problems that typically require either enormous computer resources or simplification of the problem that sacrifices accuracy. The resulting technologies will be candidates for future command and control decision aids that can assess the consequences of specific actions and strategies to better predict future results.

FY 2008 Accomplishments:

- Developed and analyzed tractable and insightful metrics and network models that expand the definition of information theory to encompass the degrees of freedom, constraints and dynamics inherent to wireless networks.
- Developed new upper bounding techniques for MANET capacity and other performance metrics, and evaluated these bounds for small to medium-sized networks.
- Developed new achievability results for key performance metrics by optimizing dynamic node cooperation and resource allocation over available degrees of freedom.

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Used rate distortion theory and network utilization to optimize the interface between networks and applications. *FY 2009 Plans:* - Predict performance in terms of throughput-delay-reliability for a specific pre-defined MANET. - Develop new achievability results for key performance metrics based on networks designed as a single probabilistic mapping with dynamics over multiple timescales. - Assess the potential for the recently developed Upper Confidence Tree (UCT) algorithm to search trees with high branching factor. - Develop features for spatial description of board position for the game of Go. - Develop algorithms and architectures for learning in a deep hierarchy, each level of which would contain invariant representations of expected data. *FY 2010 Plans:* - Predict performance in terms of throughput-delay-reliability for modest-sized MANETs with and without feedback. - Develop upper-bounding techniques that go beyond the classical bounds and inequalities for MANETs. - Develop improved methods of planning and reasoning to calculate Go best next-move hypotheses from board positions and use such hypotheses to develop a highly targeted search. - Create machine learning techniques that can assimilate huge amounts of data by creating rich representations of the input data and applying them to multiple applications. - Create non-traditional computing architectures that go beyond the currently deployed instruction-set architectures.					
Computer Science Study Group (CSSG) (U) 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		6.936	9.890	11.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
government projects. The CSSG project formalizes and focuses this research for efficiency and greater effectiveness. *FY 2008 Accomplishments:* - Developed extensive collaboration among civilian computer scientists and DoD technologists and customers. - Developed software models of human skin architecture including sensory neural system. - Developed new computational learning theory, including learning from noisy data, to enhance algorithms for random noise tolerance. - Developed software with increased capability and dependability, by combining static tools and human insight at the architectural level to defeat attacks. - Developed a process for networking wireless imaging systems and other wireless sensors emphasizing change detection and medical applications. *FY 2009 Plans:* - Identify and explore new computer science challenges that, when addressed, will yield extraordinary advances for DoD applications. - Develop a novel agent based simulation environment that will allow persons without computer programming expertise, and warfighters on the ground, air or sea down to the lowest unit levels in particular, to develop realistic new training scenarios quickly and on demand. - Develop fundamental algorithms with provable guarantees of correctness and efficiency to enable effective learning from incomplete data and data corrupted with noise. - Explore bio-inspired computing emphasizing evolutionary computation and artificial neural networks (ANNs) to solve difficult real world tasks such as autonomous guidance of vehicles. - Develop new approaches for management of network security, authentication, mobility, and handoff management with emphasis on self-organizing wireless networks in a battlefield environment. *FY 2010 Plans:* - Continue to identify and explore new computer science challenges that, when addressed, will yield extraordinary advances for DoD applications.				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Develop high-performance parallel computing, and interactive computer graphics. - Develop natural language processing techniques to enable substantial improvements in machine translation and paraphrasing, detection of deviations from normalcy and behavioral changes, and the management, sorting and accessing of textual data. - Develop reliable low-power embedded systems for continuous information gathering, access and communication; thermal and power consumption modeling for integrated circuit design.				
Programmable Matter (U) The Programmable Matter program will develop a new functional form of matter, constructed from mesoscale particles that assemble into complex 3-Dimensional (3-D) objects upon external command. These objects will exhibit all of the functionality of their conventional counterparts and ultimately have the ability to reverse back to the original components. *FY 2009 Plans:* - Build a mathematical model that theoretically confirms a viable procedure for constructing macroscopic 3-D solid objects with functional properties that have real world use. - Demonstrate externally-directed assembly of distinct macroscopic 3-D solids. - Demonstrate interlocking/adhesion of mesoscale particles to create bulk matter. - Demonstrate reversibility. *FY 2010 Plans:* - Optimize Programmable Matter properties. - Demonstrate Programmable Matter for selected applications.	0.000	4.000	7.000	
Young Faculty Award (U) The goal of the Young Faculty Award program is to encourage new faculty members of academic research institutions with innovative ideas and concepts to participate in sponsored research programs that can provide revolutionary capabilities to future defense systems. The program will also help innovative researchers better understand the needs of the DoD and interest them in working on problems with a defense relevance. The initial phase of this program focuses on speculative technologies for greatly	0.000	8.500	15.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
enhancing microsystems technologies and in the development of ideas and concepts that can lead to focused defense research programs and associated development activities to deliver a compete technology. Current activities include revolutionary advances in physics, materials, and devices to enable breakthroughs in electronics, photonics, micro and nano electro mechanical systems (MEMS/NEMS), architectures, and algorithms. *FY 2009 Plans:* - Initiate activities for research of new concepts for enhancing microsystem technologies. - Develop methodology for improving interactions between sponsored researchers and defense technologists. *FY 2010 Plans:* - Continue and initiate new activities for research of enhancements and new concepts for microsystem technologies. - Optimize approaches for obtaining maximum benefit from sponsored efforts.				
High School Science Study Group/CS Futures (U) The DARPA Grand and Urban Challenges inspired a number of high school-age students and exposed them to the rewards of a research career. The future of DoD research depends on the continuing engagement of these students in science- and technology-related fields. An offshoot of the Computer Science Study Group program, the High School Science Study Group/CS Futures program will fund efforts to identify the computer science interests of high school students, and involve them in high-level research at the high school level. *FY 2008 Accomplishments:* - Assembled a panel of academic computer scientists to identify potential areas of interest to high school students. - Established student study groups to gauge the attractiveness of the proposed ideas to students. - Conducted student evaluation of potential research to include robotics for traffic and vehicle management, robots for environmental surveillance and conservation, and object recognition for the blind.	1.000	2.000	2.000	

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
FY 2009 Plans: - Continue to engage high school study groups to work on selected ideas. - Continue evaluation of new potential ideas, including human computer interactions, computational models of environmental adaptation, and automated evaluation of physical function for applications in rehabilitation medicine. *FY 2010 Plans:* - Continue to engage high school study groups to work on selected ideas. - Continue evaluation of new potential ideas, including human computer interactions, computational models of environmental adaptation, and automated evaluation of physical function for applications in rehabilitation medicine.					
Focus Areas in Theoretical Mathematics (FAThM)* *Previously included in High Performance Algorithm Development, PE 0602702E, Project TT-06. (U) The Focus Areas in Theoretical Mathematics (FAThM) program aims to foster major theoretical breakthroughs in pure mathematics whose potential for long-term defense implications is high. By supporting closely integrated and concentrated collaborations among small numbers of leading experts, FAThM will pioneer a new approach for conducting focused research to explore fundamental interconnections between key areas of mathematics where critical insights should lead to both new mathematics and innovative DoD applications. *FY 2009 Plans:* - Establish and exploit new relations between number theory and symmetry groups of fundamental particles. - Tie advances in pure mathematics to defense applications in cryptography, quantum sciences, materials, and nano-level structures. *FY 2010 Plans:* - Establish and exploit new relations between topology and symmetry groups of fundamental particles.		0.000	1.350	1.400	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Establish and exploit new relations between the analytic foundations of symmetry and algebraic computation.				
23 Mathematical Challenges* *Previously included in High Performance Algorithm Development, PE 0602702E, Project TT-06. (U) This program aims to revolutionize the mathematical tools used by DoD in both theory and applications, discover and generate powerful and innovative new mathematics, tackle long-standing mathematical problems, and create new mathematical disciplines to meet the long-term needs of the DoD across diverse scientific and technological areas. *FY 2009 Plans:* - Develop advances in stratified Morse Theory and metric, algebraic, and hyperbolic geometries to investigate complex fluid flow. - Build and exploit deep mathematic dualities between Complex Algebraic Geometry, Algebraic and Geometrical Topology, Fourier Analysis, Geometrical Combinatorics, Theory of Oscillatory Sums, and Analytic Number Theory. *FY 2010 Plans:* - Develop integrated approach merging analysis and algebra to create new polynomial optimization algorithms. - Build and exploit deep mathematic techniques in combinatorics (the study of discrete objects) and geometry to develop new capabilities in rigidity theory for diverse applications including protein folding. - Develop theoretical guidelines for filtering multi-scale turbulent signals, incorporating new theories of data assimilation, including sparse observations. - Develop a theoretical analysis of idealized data assimilation problems in an identified complex system.	0.000	1.400	1.500	
Institute for Information Security *FY 2009 Plans:* - Complete information security initiatives.	0.000	2.500	0.000	

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C. Other Program Funding Summary ($ in Millions)

N/A

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)	**FY 2008 Actual**	**FY 2009 Estimate**	**FY 2010 Estimate**	**FY 2011 Estimate**	**FY 2012 Estimate**	**FY 2013 Estimate**	**FY 2014 Estimate**	**FY 2015 Estimate**	**Cost To Complete**	**Total Cost**
ES-01: ELECTRONIC SCIENCES	59.105	60.145	68.860						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) 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 Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
University Photonic Research (UPR) Centers	2.778	0.000	0.000	
(U) The University Photonic Research (UPR) Centers program was dedicated to coupling university based engineering research centers of excellence with appropriate industry groups to conduct research leading to development of advanced optoelectronic components. Such components are critical to enhancing the effectiveness of military platforms that provide warfighter comprehensive awareness and precision engagement. Topics researched included emitters, detectors, modulators and switches operating from infrared to ultraviolet wavelengths, and related heterogeneous materials processing and device fabrication technologies for realizing compact, integrated optoelectronic modules. *FY 2008 Accomplishments:* - Designed and fabricated prototype modules using the system-on-a-chip approach.				

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Developed testbeds capable of fully measuring and characterizing the mixed technologies implemented in the chip-scale components. - Performed fundamental, long-term research in integrated photonics science and engineering, to realize higher performance, lower energy, greater environmental stability, and adaptive behavior requirements that are needed for future DoD relevant applications. - Advanced newly developed photonics technologies and associated tools toward eventual insertion in DoD applications via industrial collaboration.					
Semiconductor Technology Focus Centers (U) The Semiconductor Technology Focus Centers research program is a collaborative effort between the Defense Advanced Research Projects Agency (DARPA), the Office of the Deputy Undersecretary of Defense for Science & Technology (DUSD/S&T), and the Microelectronics Advanced Research Corp (MARCO) which will establish new Focus Centers in “Materials, Structures & Devices” and in “Circuits, Systems & Software” at U.S. Institutions of Higher Education. The Focus Centers will concentrate research attention and resources on a discovery research process to provide radical innovation in semiconductor technology that will provide solutions to barrier problems in the path of sustaining the historical productivity growth and performance enhancement of semiconductor integrated circuits. The overall goal of this collaborative effort between the Department of Defense and industry is to sustain the unprecedented four decades of uninterrupted performance improvement in information processing power. *FY 2008 Accomplishments:* - Demonstrated, via simulation, integration of nanometer-scaled devices into circuit macro functions that have application to military sensor signal processing or advanced communications protocols. - Explored integration processes for incorporating high mobility materials as transistor channels in deeply scaled field-effect transistors. - Explored new materials and fabrication approaches to scale devices below 10 nanometers (nm). *FY 2009 Plans:* - Develop novel device fabrication and integration approaches for deeply scaled transistors and architectures for high performance mixed signal circuits for military needs.		10.200	20.000	20.000	

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Develop concepts and validation methods in one or combinations of the following areas: electronics, photonics, micro-electro-mechanical systems (MEMS), architectures and algorithms. *FY 2010 Plans:* - Continue to develop innovative approaches to the design and fabrication of scaled devices, circuits, and microsystems within multi-investigator based research consortia.					
Quantum Entanglement Science and Technology (QuEST) (U) The Quantum Entanglement Science and Technology (QuEST) program will explore the research necessary to create new technologies based on quantum information science. Technical challenges include loss of information due to quantum decoherence, limited communication distance due to signal attenuation, protocols, and larger numbers of quantum bits (Qubits) and their entanglement. A key challenge is to integrate improved single and entangled photon and electron sources and detectors into quantum computation and communication networks. Error correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Expected impacts include highly secure communications, algorithms for optimization in logistics, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking. *FY 2008 Accomplishments:* - Continued exploration of fundamental quantum systems. *FY 2009 Plans:* - Develop novel approaches to improving decoherence times. - Devise full characterization and manipulation of entangled quantum systems. - Formulate novel quantum algorithms. *FY 2010 Plans:* - Continue fundamental research in the area of Quantum Information and work towards program goals. - Develop novel approach to improving decoherence times. - Demonstrate novel quantum algorithms.		4.416	9.389	14.135	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
N/MEMS Science and Focus Centers	9.916	10.000	10.000	
(U) The goal of the N/MEMS Science and Focus Centers program is to support the development of an enhanced fundamental understanding of a number of important technical issues critical to the continuing advance of nanoelectromechanical systems (NEMS) and microelectromechanical systems (MEMS) technologies and their transition into military systems. The basic research work to be conducted under the program is responsive to recognized challenges in a comprehensive range of technical areas pertinent to future DoD needs. Industrial cost sharing is an important element of the overall effort. *FY 2008 Accomplishments:* - Fabricated non-lithographic MEMS. - Developed an understanding of fluidics on a nanoscale. *FY 2009 Plans:* - Develop MEMS enabled reconfigurable electronics. - Develop ultra-high Q (energy ratio) nanoresonators. *FY 2010 Plans:* - Continue to improve the efforts for each of the eleven centers. - Incorporate new N/MEMS fabrication methods (i.e., self-assembly). - Commence integration of MEMS power supplies.				
Semiconductor AlGaN Injection Lasers (SAIL)	1.049	3.168	0.000	
(U) This program will demonstrate semiconductor injection lasers based on Aluminum Gallium Nitride (AlGaN). In addition to demonstrating the laser performance in terms of threshold current density, operating voltage, and power output, the Semiconductor AlGaN Injection Lasers (SAIL) program will concentrate on reliability assurance and will produce lasers with stable operating characteristics. The emission wavelengths of interest are 340 nanometers and 280 nanometers. The U.S. military has a pressing requirement for compact, reliable, and cost-effective detection of bio-agents. This need is made apparent by the growing specter of the potential use of weapons of mass destruction by either terrorists or unfriendly nations. Semiconductor lasers, with their intrinsic high brightness and power will enable stand-				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
off detection applications, such as bio Light Detection and Ranging (bioLIDAR), and will greatly enhance point-detection of aerosolized bio-agents. *FY 2008 Accomplishments:* - Demonstrated pulsed lateral overgrowth of Aluminum Nitride. - Demonstrated optically pumped lasing in Aluminum Nitride. - Demonstrated high quality pulsed lateral epitaxy of Aluminum Nitride devices. *FY 2009 Plans:* - Demonstrate 340 nanometer wavelength lasers operating at room temperature under pulsed conditions. - Demonstrate stimulated emission for 280 nanometer wavelength structures.				
Nanoscaled Architecture for Coherent Hyper-Optic Sources (NACHOS) (U) The objective of the Nanoscaled Architecture for Coherent Hyper-Optic Sources (NACHOS) program is to demonstrate sub-wavelength semiconductor lasers by leveraging recent developments in reduced dimensionality and advanced feedback concepts. The specific program goal is to demonstrate injection lasers operating Continuous Wave at room temperature with cavity dimensions smaller than the vacuum wavelength of light they generate, wavelength < 1.5 micrometers. Nanoscale lasers will enable close integration of photonic and electronic devices needed in emerging high-speed processing-intense computing and communication platforms. In addition to reduced size, these lasers are expected to be power efficient and offer unprecedented modulation bandwidth. New capabilities, such as the ability to place large numbers of lasers on silicon chips, will be enabled by these devices. *FY 2008 Accomplishments:* - Demonstrated first room temperature plasmonic feedback sub-wavelength emission: Threshold power of 1 milliwatt. - Demonstrated novel new cavity design exhibiting tight confinement of plasmon modes and low-loss dielectric modes.	3.525	5.313	4.926	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
FY 2009 Plans: - Demonstrate novel heterostructures capable of gain. - Establish minimum Q factor for laser threshold. *FY 2010 Plans:* - Demonstrate sub-wavelength lasers. - Determine threshold gain under injection.				
Tip-Based Nanofabrication (TBN) (U) The Tip-Based Nanofabrication (TBN) program will develop the capability to use Atomic Force Microscope (AFM) cantilevers and tips to controllably manufacture nano-scale structures such as nanowires, nanotubes, and quantum dots for selected defense applications such as optical and biological sensors, diode lasers, light emitting diodes, infrared sensors, high-density interconnects, and quantum computing. *FY 2008 Accomplishments:* - Selected initial fabrication materials, mechanisms, and processes for optimal properties. - Completed preliminary design of specialized processing equipment. *FY 2009 Plans:* - Demonstrate nanofabrication process using a single-tip structure and associated tooling. *FY 2010 Plans:* - Fabricate a multi-tip array (5 tips) for parallel manufacturing. - Demonstrate a repeatable tip-based process and manufacturing capability.	4.528	10.995	10.799	
Quantum OptoMechanics Integrated on a Chip (U) The objective of this program is to leverage advances in Photonics and Micro fabrication to develop integrated chips capable of exploiting quantum optomechanical applications. Although light is usually thought of as carrying energy but relatively little momentum, light confined to a high-finesse cavity can	0.000	0.000	4.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
exert significant force on the cavity mirrors. When the mirror is allowed to vibrate by coupling it to a mechanical (spring-like) system, energy can be transferred between coupled optomechanical resonators. Depending on the detuning of the cavity, one can obtain either damping (cooling) or amplification (heating) of the mirror motion. Notable achievements in this field are the demonstration of mirror cooling (damping of the internal degree of motion) to sub-Kelvin (6 mK) temperatures and demonstration of radiation driven high-Q, high-frequency (1 GHz) oscillators. With sufficiently high cavity finesse and Q's of the mechanical system, it is possible to reach a regime in which the mirror motion is no longer thermally limited. Instead, it becomes limited by the quantum mechanical radiation pressure force. Once this limit is reached, it is possible to take advantage of quantum mechanical effects without having to cool the system. It is anticipated this will result in a new generation of mass-sensing devices and ultra high-Q, high-frequency resonators controlled by light. In optical systems, it will be possible to efficiently squeeze light beyond the standard shot-noise limit producing light sources for infrared detection and quantum information applications. *FY 2010 Plans:* - Demonstrate resonant frequency of 10 megahertz (MHz). - Demonstrate Mechanical Q of 1x10^6.				
Centers for Integrated Photonics Engineering Research (CIPhER) (U) The Centers for Integrated Photonics Engineering Research (CIPhER) program will explore and enhance fundamental understanding in the development and application of integrated photonics, in which an entire photonic system is fabricated on a single chip. Much like integrated electronics, integrated photonics has the potential to enable photonics systems to reach revolutionary new levels of performance and functionality, but with a wider application range than electronics, including such areas as imaging, energy conversion, signal processing, and computing. The rise of integrated photonics as a viable, practical technology, combined with the utility of integrated photonics to many applications, is slated to result in a more rapid transition of basic photonics research to system applications of importance to the Department of Defense. As such, photonics research that is supported by organizations with both fundamental and commercial interests is ideally suited to fostering the growth of the nation's integrated photonics industry. The CIPhER program will therefore use a government/industrial cost-share funding	0.000	0.000	5.000	

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
model to foster the next generation of fundamental university-based photonics research. The CIPhER program is directed toward achieving this objective through the establishment of collaborative theme-based focus centers. Focus centers will be comprised of university-led teams, with industrial partners, engaged in long-term basic research of photonic materials, devices, and microsystems. *FY 2010 Plans:* - Initiate the development and investigation of new integrated photonics concepts for application to microsystems in: Imaging Science and Technology, Energy Conversion and Manipulation, Chip-scale Signal Processing and Computing, and Chemical/Biological Sensing and Processing.					
Molecular Photonics (MORPH) (U) The Molecular Photonics (MORPH) program explored large dendritic and other highly branched organic molecules that offer great potential for active photonic applications. Three-dimensional molecular structures and shapes can be engineered to orient and immobilize optically active substituents to achieve much higher electro-optic activity than with traditional polymer systems. The ability to engineer molecular structure, shape, energy transport, and chemical composition offers the potential for distinct electronic energy level engineering without the traditional semiconductor crystal lattice. Potential applications include: direct conversion of sunlight to power (“optical antenna”), inversion-less lasers and electromagnetically induced transparency (coherent organic emitters, and slow light materials), high performance photorefractive materials for signal processing and holographic memory, optical limiters and saturable absorbers as well as high performance modulators. *FY 2008 Accomplishments:* - Demonstrated a very high speed (100 gigahertz) polymetric electro-optic (EO) modulator. - Demonstrated organic materials for building ultra-high speed EO modulators. - Developed tailored organic materials as high-efficiency optical limiters in regions of the spectrum relevant to military sensor protection.		8.000	0.000	0.000	
Illinois Institute of Technology		1.040	0.000	0.000	

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
(U) The Illinois Institute of Technology program explored new approaches to advanced electronics technology. *FY 2008 Accomplishments:* - Initiated development of advanced electronics technologies.				
Advanced Photonic Composites Research (U) The objective of Advanced Photonic Composites Research program is to develop advanced optical composites for defense applications. *FY 2008 Accomplishments:* - Transitioned nano-engineered materials and composites into DoD relevant devices with a specific focus on advancing infrared detectors and energy harvesting structures. - Developed and commercialized composite technology in integrated optics. *FY 2009 Plans:* - Continue photonic composite development.	3.253	1.280	0.000	
Nanoscience Nanotechnology Institute (U) The Nanoscience Nanotechnology Institute explored new approaches to nanoscience research. *FY 2008 Accomplishments:* - Initiated nanoscience research.	2.400	0.000	0.000	
Focus Center - Government Industry Cooperative University Research (GICUR) (U) The Focus Center - Government Industry Cooperative University Research (GICUR) program compliments the goals and objectives of the Semiconductor Technology Focus Centers. All plans are identical. All funding is applied to the Semiconductor Technology Focus Center program.	8.000	0.000	0.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
FY 2008 Accomplishments: - Explored integration processes for incorporating high mobility materials as transistor channels in deeply scaled field-effect transistors. - Explored new materials and fabrication approaches to scale devices below 10 nanometers.				

C. Other Program Funding Summary ($ in Millions)

N/A

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)	FY 2008 Actual	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
MS-01: MATERIALS SCIENCES	42.474	50.681	52.762						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) This project provides the fundamental research that underpins the development of advanced nanoscale and bio-molecular materials, devices and electronics for DoD applications.

B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
Nanoscale/Biomolecular and MetaMaterials	8.000	12.583	11.829	

(U) The research in this thrust area exploits advances in nanoscale and bio-molecular materials, including computationally based materials science, in order to develop unique microstructures and material properties. This area also includes efforts to develop the underlying physics for the behavior of materials whose properties have been engineered at the nanoscale level (metamaterials) and materials exhibiting a permanent electric charge (charged matter).

FY 2008 Accomplishments:

- Developed efficient computational methods that correctly predict the properties of excited electronic states in high intensity laser.
- Achieved mid-wave infrared optical transmission comparable to that of spinel and worked toward achieving a composite material with mechanical properties comparable to those of sapphire in yttria-magnesia nanocomposite material.
- Achieved first-ever optical model for nanomaterials of interest and transitioned it to the research community.
- Achieved yttria, nano silicon carbide optical ceramics with required strength of sapphire and worked toward optical properties of spinel.

FY 2009 Plans:

- Demonstrate automated laser beam front diagnostic and adaptive beam correction.

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Demonstrate simultaneously infrared optical transmission comparable to spinel and mechanical properties comparable to sapphire in 75mm discs. - Develop new materials with both optical properties and strength into 75mm flat discs. - Characterize the material properties of 75mm discs through testing in relevant environments. - Demonstrate the ability to provide surface strengthening through compressive materials. - Investigate new methods of altering diatom structures and adapting diatom materials to facilitate new sensors and devices. *FY 2010 Plans:* - Initiate development of new materials into hemispherical domes with decreased optical scatter, doubled mechanical strength, and doubled thermal shock capabilities over single crystal sapphire. - Characterize the material properties of hemispherical domes through testing in relevant military environments. - Characterize the material properties of non-hemispherical domes. - Develop inexpensive processing techniques to create customized diatom derived sensors and devices. - Ion: demonstrate ability to affect airflow around the surface of an airfoil using ions accelerated across multiple points to generate an airstream on the surface of the airfoil. - Radiometer: demonstrate ability to produce significant forces on aerofoil-shaped surfaces. - Establish the material science of charged matter by developing underlying technology and defining range of applicability. - Demonstrate in a laboratory environment charged matter properties including superadhesion, frictionless surfaces, and resistance to electrostatic charging.					
Engineered Bio-Molecular Nano-Devices and Systems (U) The Engineered Bio-Molecular Nano-Devices and Systems program seeks to develop and demonstrate engineered bio-molecular nano-scale devices that harness nature's nanophotonic structures to enable controllable photonic devices at visible wavelengths, enable real time observation and analysis of bio-molecular signals, thus enabling single molecule sensitivity with the simultaneous exploitation of the temporal domain (i.e., stochastic sensing). Arrays of such devices will enable an order of magnitude (10 to 100 times) reduction in the time required for analysis and identification of known and unknown		6.574	10.698	10.500	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
(engineered) molecules. The potential to engineer lightning will be investigated. This program will also develop novel nanomaterials for exquisitely precise purification of materials, enabling such diverse applications as oxygen generation and desalination. This program will compare the phenomenology of various biological, physical and social systems and abstract the common features that are responsible for their properties of self-organization and emergent behavior. *FY 2008 Accomplishments:* - Demonstrated a stochastic sensing system using a mutant protein pore in a non-laboratory setting. - Demonstrated a probability of detection greater than 99.5% and an extremely low false alarm rate with Chemical Warfare Agents (CWA) simulants and CWA interferent simulants. - Developed and prototyped a multi-element (4) array of stable sensor elements. - Used ultra-high-speed cameras, electric field mills, radio frequency (RF) sensors and scintillation detectors to simultaneously record the development of lightning stepped leaders, while simultaneously measuring associated X-rays, electric fields, and magnetic fields in order to improve lightning initiation and propagation models. - Used lightning initiation and propagation models to characterize the conductivity of the stepped leader channel just prior to the initiation of lightning and the first return stroke for troop, asset, and ordnance protection for surface fields greater than 4 kilovolts per meter (KV/m) and for surface fields greater than 6 KV/m. - Designed, fabricated and integrated a prototype dual-energy filter into the Volumetric Angio Computed Tomography (VAC) imaging test bed to allow dual energy imaging and the detection of occult bleeding in battlefield casualties. - Established and successfully tested a Figure-of-Merit for multiple simulated filter configurations and the imaging testbed filter implementation. - Derived a new image reconstruction algorithm that meets de-blurring sampling requirements. *FY 2009 Plans:* - Develop novel mathematical tools that enable design of revolutionary molecular structures and tailoring of properties.				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Design novel structures based on these mathematical tools and correlate geometric characteristics with spectroscopic characteristics. - Identify configurational properties of candidate structures that result in unique spectroscopic characteristics. - Construct preliminary lightning safety model from the ground-based measurements in FY 2008 for the critical conditions of safe military operations for personnel and ordnance. - Develop fabrication processes for a reproducible, transmission anode with two times increased yield and efficiency and suitable for integration into the sealed transmission anode X-ray tube. - Select the best overall transmission anode fabrication process for further development. *FY 2010 Plans:* - Calculate the quantum mechanical characteristics of these mathematically inspired novel molecular structures developed in FY 2009. - Characterize the electronic and vibrational properties of candidate structures from their quantum properties. - Verify via simulation that selected materials possess desired properties. - Use ground-based, arial and space-based assets to measure optical, RF, magnetic, X-ray and gamma ray events associated with rocket triggered lightning. - Develop, validate and improve a 3-D model of critical conditions and processes in clouds and the atmosphere. - Develop a set of candidate biological, physical, and social systems for investigation and construct a qualitative description of their commonalities. - Develop an initial simulation system for implementing the concepts developed. - Develop a quantitative theory that describes the fundamental features of intelligence evidenced in the various systems examined. - Low cost, lightweight, portable photovoltaics (PoP) will explore all aspects of portable photovoltaic (PV) devices: light acquisition, energy capture, carrier extraction, robust and durable portability, and flexibility to identify most advantageous breakthroughs for portable PV devices. - Demonstrate understanding of interaction of nano-structure with light and gas molecules. - Demonstrate initial fabrication of nanophotonic structures.				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
Atomic Scale Materials and Devices	13.100	13.800	14.901	

(U) This thrust examines the fundamental physics of materials at the atomic scale in order to develop new devices and capabilities. A major emphasis of this thrust is to provide the theoretical and experimental underpinnings of a new class of semiconductor electronics based on spin degree of freedom of the electron, in addition to (or in place of) the charge. A new all optical switch capability will also be investigated. It includes a new, non-invasive method to directly hyperpolarize biological tissues, leading to novel quantitative neurodiagnostics. 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 new capabilities in the quantum regime, for example, GPS-independent navigation via atom interferometry as well as the potential to generate significant heat from deuterated palladium.

FY 2008 Accomplishments:
- Demonstrated Rubidium atomic clock with line-width below 20 Hz (less than twenty percent natural line-width).
- Demonstrated quantum kicked rotor technique to reduce decoherence in atom interferometer.
- Demonstrated high-throughput optical lattice systems for improved simulation time and stable frequency metrology.
- Developed real-time, modular system for experimental control, monitoring, and data acquisition.
- Designed optical system to produce flat-top transverse beam profile for homogeneous optical lattice.
- Demonstrated production of bi-photon pairs and arbitrary amplitude modulation of bi-photon wavefunction.

FY 2009 Plans:
- Demonstrate rotationally sensitive interferometer with sensitivity greater than one radian per earth rotation rate.
- Emulate two-dimensional (2-D) Bose-Hubbard Model phase diagram in less than twelve hours that confirms theoretical calculations.
- Install flat-top beam profile system in experimental chamber; verify production of homogeneous optical lattice potential.

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Engineer strong optically-induced absorption materials for all-optical switch (or equivalent device) with ultra-low energy dissipation per operation. - Design all-optical switch (or equivalent device) based on optically-induced absorption. - Develop theoretical techniques to extract relevant model-independent thermodynamic quantities from ensemble absorption images. - Demonstrate non-local modulation of bi-photon wavefunction and demonstrate single photon non linear switch. - Establish the parameters necessary to achieve high levels of deuterium loading with a minimum of electrochemical power. - Initiate development of the capability to reproducibly generate significant increases in excess heat using electrochemically stimulated, highly deuterated palladium. *FY 2010 Plans:* - Develop cooling and precision thermometry techniques for fermionic atoms in optical lattice. - Develop quantum gas microscope with sufficient resolution to image individual atomic sites in 2-D optical lattice; verify by imaging atomic gas trapped in lattice. - Emulate XXZ quantum spin model using ion crystal array in less than twelve hours that confirms theoretical calculations. - Develop the core materials fabrication techniques that will enable extremely low-power, extremely high density, all-oxide, transistor-like switches with a ferroelectric gate and a high density, 2-D interfacial oxide electron gas exhibiting metal-insulator transition in response to an applied gate voltage. - Model how these transistor-like devices will support corresponding device architecture for advanced reconfigurable logic and memory. - Design broadband, frequency comb spectroscopy system with sensitivity better than ten parts per billion acetylene at 1.5 microns. - Evaluate performance improvements from, and system configuration changes needed to, shift comb central wavelength from 1.5 microns to 3 microns. - Quantify the effects of impurities in palladium substrate material on the capability to generate excess heat.				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Quantify the required dynamic loading and relaxation conditions and optimize the palladium substrate composition and microstructure required to achieve high levels of deuterium loading and tolerate the high stresses associated with these conditions. - Establish the effects of surface area and crystal orientation on degree of deuterium loading and the loading/relaxation dynamics and correlate these effects with increases in excess heat generated. - Demonstrate all-optical switch (or equivalent device) based on optically-induced absorption. - Demonstrate total energy dissipation for an optical switch (or equivalent device) of less than 1 femtojoules per operation, and signal loss of less than 0.1 dB, excluding waveguide losses before and after device. - Demonstrate soft X-rays with specific states of orbital angular momentum. - Initiate a series of experiments using the High Frequency Active Auroral Research Program (HAARP) facility to study ionospheric and trans-ionospheric phenomena, including optimization of high frequency to very low frequency conversion efficiency, generation and propagation and characterization of artificial ducts, and triggering and characterization of specific ionospheric instabilities.				
Surface Enhanced Raman Scattering (SERS) - Science and Technology Fundamentals	5.000	8.000	8.475	
(U) The Surface Enhanced Raman Scattering (SERS) - Science and Technology program focuses on the fundamental technical challenges facing potential sensor performance with respect to their sensitivity, selectivity, enhancement factors and development. SERS nanoparticles have considerable potential for both chemical and biochemical sensing applications due to: 1) their potential large spectral enhancement factors, 2) the nature of spectral fingerprints that can be expected to yield low false alarm rates, and 3) the capability for detecting targeted molecules at useful stand-off ranges. This program seeks to identify and overcome the key scientific and technical challenges necessary for replacing existing sensors of chemical and biological warfare (CBW) agents with SERS-based sensing approaches. *FY 2008 Accomplishments:* - Developed understanding of nanoparticle shape and its effect on SERS enhancements; examined high quality resonators for SERS applications.				

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B. Accomplishments/Planned Program ($ in Millions)		**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
FY 2009 Plans: - Develop methods to engineer nanoparticles with one nanometer feature sizes (separation) on a macroscale. *FY 2010 Plans:* - Begin assembly or fabrication of one inch SERS active substrates capable of 10^9 enhancements.					
Casimir Effect Enhancement (CEE) (U) This program's goal is to manipulate materials properties and geometries in order to enable repulsive Casimir forces at interfaces. This can lead to increased reliability in Micro Electrical Mechanical Systems (MEMS) devices by eliminating stiction, reduced drag and increased fuel efficiency in all military systems (boats, airplanes, etc.), or enhancing any system where attractive forces hinder overall performance. *FY 2010 Plans:* - Model potential systems where Casimir forces can be manipulated. - Experiment to confirm ability to reduce Casimir force. - Demonstrate nanomechanical device with observable, repeatable ten percent reduction in adhesive forces.		0.000	0.000	4.057	
Dynamics-Enabled Frequency Sources (DEFYS) (U) The Dynamics-Enabled Frequency Sources (DEFYS) program will develop components to enable navigation and control systems for advanced weapons systems operating in high-G environments. DEFYS will revolutionize frequency sources by moving to nanoscale mechanical devices enabling low-phase noise performance better than Quartz from an easily integrated package. The program will use novel mechanisms in nonlinearities and background noise, while incorporating temperature stability and acceleration sensitivity to provide performance exceeding currently predicted limits. *FY 2010 Plans:* - Demonstrate first mechanism, use nonlinearity to eliminate phase noise from amplifier jitter. - Work at state-of-art frequencies to facilitate concentration on novel mechanism.		0.000	0.000	3.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
Quantum Sensors (U) The Quantum Sensors program developed approaches to exploit non-classical effects called entanglement to improve the resolution and range of military sensors. Quantum sensors retain the generally better propagation characteristics of long wavelength light while achieving the better spatial resolution of short wavelength radiation. Conventional classical sensors rely on light with shorter wavelengths, like blue light, to produce sharp images. As wavelengths increase, for example from blue to infrared, the classical resolution decreases. Quantum sensors will be able to retain high resolution as the wavelength increases using a non-classical effect called entanglement. Two broad classes of sensor are under consideration. Type I quantum sensors propagate entangled photons to a target and back to a detector, where quantum effects may enhance resolution. Type II quantum sensors propagate classical radiation to the target, and entangled photons are used within the detector to improve resolution. A third class of approach, based on ghost imaging, is also being explored. As the program transitions from the theoretical proof stage to the subsystem design stage in FY 2009 it will move to the Electronic Technology PE 0602716E, Project ELT-01. *FY 2008 Accomplishments:* - Continued studies of Type I, Type II, and ghost imaging sensor concepts to establish whether they are robust to military targets and environments. - Completed experiments on outdoor propagation of non-classical states.	4.800	0.000	0.000	
Comparative Genomics for National Security Goals/Infectious Disease Research *FY 2008 Accomplishments:* - Examined prognostic epidemiology using comparative genomics. - Developed software program for phylogenic analysis of DNA and other data using dynamic homology. *FY 2009 Plans:* - Promote community interaction and create user groups to test software program and improve system. - Identify parameters needed for research areas of transition partners.	1.000	2.000	0.000	
Institute for Collaborative Sciences Research	0.000	1.200	0.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
FY 2009 Plans: - Investigate a collaborative sciences research effort.				
Advanced Materials Research Institute *FY 2008 Accomplishments:* - Investigated use of nanoparticles and nanowires to improve chemical electron mobility and/or magnetic energy storage product relative to bulk materials. *FY 2009 Plans:* - Investigate nanoscale engineering of multiferroic materials, and implementation of voltage controlled ferromagnetism for micro- and nano-scale devices.	4.000	2.400	0.000	

C. Other Program Funding Summary ($ in Millions)

N/A

D. Acquisition Strategy

N/A

E. Performance Metrics

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