RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)							DATE February 2005	
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research			R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, R-1 # 1					
COST (In Millions)	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	130.223	169.571	130.090	132.041	140.339	145.893	153.596	153.596
Bio/Info/Micro Sciences BLS-01	40.602	57.779	52.389	52.180	56.794	60.925	64.925	64.925
Information Sciences CCS-02	14.872	23.791	19.933	21.958	23.751	23.951	24.951	24.951
Electronic Sciences ES-01	27.854	33.965	23.783	23.453	25.169	25.679	26.752	26.752
Materials Sciences MS-01	46.895	54.036	33.985	34.450	34.625	35.338	36.968	36.968

(U) Mission Description:

(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, 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 length scales of biological architecture and function, from the molecular and genetic level through cellular, tissue, organ, and whole organisms' levels. Key focus areas include multidisciplinary programs in BioComputational Systems; Simulation of Bio-Molecular Microsystems; Bio Interfaces; Biological Adaptation, Assembly, and Manufacturing; Nanostructure in Biology; and Human Assisted Neural Devices.

(U) The Information Sciences project supports basic scientific study and experimentation for national security requirements such as computational models, new mechanisms for performing computation and communication, innovative approaches to the composition of software, novel human computer interfaces, novel computing architectures, and automatic speech recognition research.

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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.

(U) Program Change Summary: *(In Millions)*

	FY 2004	FY 2005	FY2006	FY2007
Previous President's Budget	139.434	143.729	146.565	148.723
Current Budget	130.223	169.571	130.090	132.041
Total Adjustments	-9.211	25.842	-16.475	-16.682
Congressional program reductions	0.000	-7.558		
Congressional increases	0.000	33.400		
Reprogrammings	0.000	0.000		
SBIR/STTR transfer	-9.211	0.000		

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(U) Change Summary Explanation:

FY 2004	Decrease reflects SBIR/STTR transfer.
FY 2005	Increase reflects ten congressional adds in the areas of nanotechnology, photonics and electronics offset by a congressional reduction to the Biointerfaces program and undistributed reductions.
FY 2006 - 2007	Decrease reflects reduced emphasis on Simulation of Bio-Molecular Microsystems (SIMBIOSYS) and maturation of Bio/Info/Micro efforts into 6.2.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research			R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01					
COST (In Millions)	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Bio/Info/Micro Sciences BLS-01	40.602	57.779	52.389	52.180	56.794	60.925	64.925	64.925

(U) Mission Description:

(U) This project will investigate and develop 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.

(U) Program Accomplishments/Planned Programs:

	FY 2004	FY 2005	FY 2006	FY 2007
BioComputational Systems	8.000	9.237	6.500	6.750

(U) The BioComputational Systems (BioCOMP) component seeks to use computation to enhance biology and to use biology to enhance computation. The BioCOMP program will explore and develop computational models of bio-molecular processes in living cells that will enable a range of novel DoD capabilities for bio-agent threat assessment, force health protection, and bio-sensor design. In addition, the program will explore new biologically-inspired computing principles of robust information processing systems.

(U) A primary thrust of the BioCOMP program is the development of cutting edge computational models and tools for predictive systems biology and the demonstration of these tools in Defense applications. These computer prediction methods will give the warfighter more information about biological threats in far less time than today's costly wet-lab methods.

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(U) A critical challenge in the post-genomic era is to utilize genomic information to model and characterize systems of bio-molecular networks and pathways underlying biological mechanisms at the cellular level. Models of complex gene-protein interactions will enable simulation, dynamic analysis, prediction and control of cellular processes. Based on these models, the program is developing Bio-SPICE (Simulation Program for Intra-Cell Evaluation), an open software framework providing innovative models and analysis tools. The extensible design of Bio-SPICE allows for adding, refining and customizing of the Bio-SPICE models and tools for specific cell processes.

(U) Technical challenges to developing Bio-SPICE are met in several ways. First, four-dimensional (4-D) computational models are being developed to capture spatio-temporal interactions of gene-proteins in cellular mechanisms. This includes hybrid analog-discrete models of biochemical reactions, small concentration reactants, asynchronous and stochastic computation, and reaction-diffusion spatial models. Second, cognitive information processing tools will be exploited to rapidly extract and incorporate molecular interaction information from structured and unstructured databases and scientific publications in the private and public domain. Third, new 4-D simulation techniques are being developed that can scale to large numbers of gene-protein interactions. To transition the technology, the program is collaborating with several DoD client agencies including Defense Threat Reduction Agency (DTRA), U.S. Army Medical Research and Material Command (USAMRMC), Soldier Biological and Chemical Command (SBCCOM), Walter-Reed Army Institute for Research (WRAIR), Naval Medical Research Command (NMRC), the U. S. Air Force Toxicology program, and the Center for Disease Control and Prevention (CDC).

(U) Program Plans:

- Develop a progressively sophisticated suite of dynamic cellular models and architecture for Bio-SPICE, which will enable modeling, prediction, and control of cellular processes. Continually validate results through experimentation.
- Continue to incorporate spatial models into Bio-SPICE and explore potential reduced-order models to analyze the non-linear and stochastic dynamics of thousands of interactions.
- Investigate scalable and extensible implementation of Bio-SPICE that utilizes a distributed computing architecture supporting a rich set of spatio-temporal models to handle vast amounts of experimental data for prediction and analysis.
- Build baseline models of intra-cell processes of interest to DoD, such as spore formation in bacteria like the anthrax, bacterial cell division and growth, and cell death induced by toxins from bio-warfare agents (apoptosis). Identify candidate molecular targets for intervention strategies in sporulation (such as for therapeutics and safe decontamination), cell cycle control, and other processes in defense against bio-agents.

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- Demonstrate computer analysis methods for commanders to use in the threat assessment of natural and emerging bio-agents. These methods, which predict pathogenicity and virulence of agents from their genomic information, will be far more informed than today's costly wet-experiments.
- Identify new methods for early detection of exposure of soldiers to pathogens and toxins using molecular (gene expression) signatures, which is vital for early intervention and avoidance of death.
- Develop a framework for describing and representing biological knowledge that spans data from molecular (genomic, proteomic) to clinical level, and across organisms, to support deep and rapid knowledge extraction.
- Implement cutting edge learning and reasoning algorithms that act on vast amounts of biological experimental and simulation data, and demonstrate rapid reasoning and knowledge-acquisition.

	FY 2004	FY 2005	FY 2006	FY 2007
Simulation of Bio-Molecular Microsystems (SIMBIOSYS)	9.000	9.000	5.000	3.000

(U) The Simulation of Bio-Molecular Microsystems (SIMBIOSYS) program will focus on methods to dramatically improve the interaction and integration of biological elements with synthetic materials in the context of microsystems. Specifically the SIMBIOSYS program will develop methods and tools to simulate and design Bio-Molecular Microsystems with a high degree of multi-disciplinary integration. This will be accomplished by exploring fundamental properties and compatibility of biological elements at the molecular surface level through experimental and theoretical analyses. Key phenomena to be studied include molecular recognition processes, signal transduction phenomena, and micro- and nano-scale transport of biological molecules. Engineering of biological systems may be used to manipulate these fundamental characteristics and optimize the integration of biological elements with synthetic materials for information collection. It is expected that significant advancements in devices that utilize or mimic biological elements will be realized including sensors, computational devices and dynamic biological materials for force protection and medical devices.

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(U) Program Plans:

- Demonstrate high (signal to noise ratio [SNR] > 10) transduction of molecular signals into measurable electrical and mechanical signals using nanopores, micro/nano-cantilevers, and nanoparticles; demonstrate SNR ~ 100 using solid-state nanopores for DNA translocation and using nanopores for ultraselective DNA detection; demonstrate models to correlate transduced signal intensity to bio-molecular structure and binding events.
- Demonstrate that, using microcantilevers, a nanoparticle conjugation can successfully enable detection of 10-100 atto-molar DNA concentrations with single base pair selectivity without performing polymerase chain reaction; transition to other DoD agencies and Homeland Defense.
- Demonstrate low power transport (~ 10X reduction in power) of fluids by modulating surface tension in droplet based transport.
- Demonstrate surface-tension modulated transport of droplets on a substrate; demonstrate computational models to optimize transport characteristics.
- Demonstrate orders of magnitude (> 100X) improvement in microfluidic mixing using electrokinetic and Magneto Hydrodynamic (MHD) schemes (based on modeling studies).
- Develop scaling laws and phenomenological models for bio-molecular phenomena such as molecular recognition, signal transduction and bio-fluidic transport processes in bio-microfluidic systems; develop and implement scaling laws into microfluidic system modeling software to enable design of lab-on-a-chip systems.
- Design novel hybrid macro-molecular devices that form specific and controlled transducing functions at the molecular scale; demonstrate design of maltose binding proteins and ion channels with desired selectivity and sensitivity using computational tools.
- Design and demonstrate working devices that incorporate biological elements as sensors, actuators and computational devices.

	FY 2004	FY 2005	FY 2006	FY 2007
Bio Interfaces	5.366	4.000	4.000	4.750

(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. Chief among them is the ability to seamlessly integrate and control mechanical devices and sensors within a biological environment – a critical aspect in the successful implementation of a major prosthetics effort.

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In addition, these tools will help exploit the advances in such fields as neuroscience. It is also expected that understanding the fundamentals of biology will aid in developing tools to understand complex, non-linear networks and force structures.

(U) Program Plans:

- Manufacture the world's smallest nanofluidic channels (~2 nm in diameter) for parallel processing of single biomolecules; create microfluidic devices for trapping developing insect embryos for analysis of biological materials (e.g., pathogens); create a multi-cantilever field effect transistor for measuring single cell physiology.
- Develop new algorithms based on wavelets and superparamagnetic resonance for sorting neuronal spike data; develop a Bayesian network framework for analysis of cellular regulatory networks; develop a hybrid computational model for representing tissue differentiation; develop a software tool for analysis of high dimensional gene expression data.
- Examine behavior of materials/biological interfaces to improve performance and biocompatibility of mechanical and microelectronic devices for ultimate integration into new prosthetic devices.
- Develop mathematical approaches and new microelectronic devices for sensing and controlling biological responses.
- Demonstrate and validate novel mathematical tools for analyzing and interpreting complex data sets obtained from complex biological systems and behavior. Extend these tools to other problems of interest to DoD.
- Exploit advances in neuroscience, sensors and real-time signal processing techniques to gain access to neural signatures previously undetected. Potential future DoD applications would include new approaches to training as well as the ability to improve the throughput and accuracy of intelligence imagery analysis.

	FY 2004	FY 2005	FY 2006	FY 2007
Biological Adaptation, Assembly and Manufacture	6.200	11.200	11.889	11.500

(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 of Defense needs (such as blood or other therapeutics). In addition, the fault tolerance present in biological systems will be exploited in order to

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assemble and manufacture complex physical and multi-functional systems, both biological and abiotic. Further activity in this area will investigate the communication between adaptive elements within biological systems, including biofilms, as they develop in space and time, and uncovering the fundamental informational and physical architectures that underlie this unique biological property. Applications to Defense systems include the development of chemical and biological sensors, and improved battlefield survivability of the warfighter.

(U) Program Plans:

- Identify promising strategies in nature that allow organisms to survive under environmental extremes and adapt those strategies to other cells, tissues, organs and organisms, including platelets and red blood cells.
- Understand biological methods for controllable and reversible adhesion and adapt these methods to material systems that can be used for a wide range of Defense applications (e.g., wall climbing).
- Understand how cells and organisms can be engineered to adapt to environmental chemicals and toxins of interest to DoD by producing signals (colors, fluorescence) that can be detected remotely.
- Develop approaches for engineering biofilms for a variety of DoD applications including sensing; reporting and removing agents of interest from the environment; power generation; and systematically evaluating mechanisms of biofilm induced failure in metals, welds, and fabrications methods due to corrosion.
- Develop methods to heal limb-threatening wounds without loss of function through approaches that lead to the regeneration of functional tissue (muscle, bone, etc.) rather than debilitating scar tissue.
- Demonstrate the adaptation of bacteria to the digestion of cellulose in disaccharides to enable the ability to use cellulose (e.g., grass) as nutrition and for the prevention of dysentery.

	FY 2004	FY 2005	FY 2006	FY 2007
Nanostructure in Biology	5.036	10.442	10.000	11.180

(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 will provide important new leads for the development of threat countermeasures, biomolecular sensors and motors, and molecular interventions to maintain human performance in the battlefield. This program will also develop approaches to mathematically predict a priori the structure of biological materials, especially

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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). 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. Finally, this thrust supported the early, basic work in biomagnetics, which has now been transferred to PE 0602715E, Project MBT-02.

(U) Program Plans:

- Demonstrate proof of concept for using nanomagnetics to detect and manipulate individual cells and biomolecules.
- Investigate fundamental issues of nanowire communication with electrically active biological systems (neurons) including high density recording, information processing, stimulation patterns, and new computational methods of analysis.
- Demonstrate image formation through the use of microchip-driven wire to simultaneously stimulate thousands of retinal neurons.
- Demonstrate the ability to rapidly (hours as opposed to weeks or months) predict new protein structures that inactivate new biological pathogens or toxins.
- Demonstrate approaches for making enzymes that catalyze chemical reactions not performed by natural enzymes for the synthesis of chemicals of interest to the Department of Defense.

	FY 2004	FY 2005	FY 2006	FY 2007
Human Assisted Neural Devices (formerly Brain Machine Interface)	7.000	12.000	15.000	15.000

(U) This program will develop the scientific foundation for novel concepts that will improve warfighter performance on the battlefield as well as technologies for enhancing the quality of life of paralyzed veterans. This will require an understanding of neuroscience, significant computational efforts, and new material design and implementation. Closed-loop control of peripheral devices using brain signals will be examined. Examination of different brain regions will be accomplished in order to generate coded patterns to control peripheral devices and robotics. Techniques will be examined to extract these signals non-invasively. This effort will be conducted with the Veteran's Administration to ensure approaches are compatible with prosthetic requirements. Technologies developed by this program will be exploited by the Revolutionizing Prosthetics program in PE 0602715E, Project MBT-02.

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(U) Program Plans:

- Extract neural and force dynamic codes related to patterns of motor or sensory activity required for executing simple to complex motor or sensory activity (e.g., reaching, grasping, manipulating, running, walking, kicking, digging, hearing, seeing, tactile).
- Determine necessary force and sensory feedback (positional, postural, visual, acoustic, and other) from a peripheral device or interface that will provide critical inputs required for closed-loop control of a prosthetic.
- Explore new methods, processes, and instrumentation (e.g., Magnetoencephalography, optical, IR, and RF) for accessing neural codes non-invasively at appropriate spatiotemporal resolution to provide closed-loop control of a peripheral device.
- Demonstrate real time control for recognizing and picking up an item and manipulating it in a realistic complicated environment.
- In partnership with Veteran's Administration and Walter Reed Army Medical Center, demonstrate the ability to use neural codes for closed loop control of a prosthetic device.

	FY 2004	FY 2005	FY 2006	FY 2007
Bio Detection of Unexploded Ordnance & Land Mines	0.000	1.900	0.000	0.000

(U) Continue to develop bee-based UXO detection as a viable technology for landmine detection. Research tasks will focus on the development of a cost effective, reliable and easy-to-use bee detection system for the DoD, countermine, and homeland security communities.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project CCS-02

COST (In Millions)	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Information Sciences CCS-02	14.872	23.791	19.933	21.958	23.751	23.951	24.951	24.951

(U) Mission Description:

(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-computer and computer-to-computer interaction technologies; innovative approaches to the composition of software; and new learning mechanisms for systematically upgrading and improving these capabilities. Promising techniques will transition to both ongoing and system-level projects.

(U) Program Accomplishments/Planned Programs:

	FY 2004	FY 2005	FY 2006	FY 2007
Computer Exploitation and Human Collaboration	14.872	23.791	19.933	21.958

(U) The Computer Exploitation and Human Collaboration program is developing highly innovative information processing technologies that will allow warfighters and commanders of the future to interact intuitively with computers, enable a new generation of collaboration methods and information acquisition in a natural way, and provide intelligent seamless exchange of information in a world where computing devices are ubiquitous and heterogeneous. The program is exploring new human-machine interaction (HMI) paradigms where computing and communications systems reason about warfighter's and commander's goals and capabilities, and use this information to drive the interaction. Technical challenges include architectures for software agents (including mobile code); redesign of classical computer operating systems; secure exchange of information over insecure channels; and robust, natural modes for increasing information and knowledge; and organizing both into easily retrievable, re-usable forms. Research is addressing breakthrough techniques for distilling key concepts from massive amounts of information and novel information presentation modes to provide concise, salient situational awareness. Work includes creation of powerful multi-agent systems and tools for effective decision-making and analysis in complex, multi-participant environments; high-performance, user-centered interfaces capable of understanding the warfighter and commander's combined natural communication and activity patterns; and

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fundamental technologies for integrating information expressed in different modalities and formats, which is currently a critical bottleneck to timely military situational awareness.

(U) The Computer Exploitation and Human Collaboration program is also exploring the fundamental science of interconnected systems to provide powerful mathematical tools for understanding the intrinsic properties and complexities of large-scale networks and other distributed systems. This foundational research is imperative for future design of robust systems that break out of the established tradition of piece-wise patching current infrastructures. The resulting mathematical tools will allow development and defense of critical infrastructures; and create more efficient, reliable data networks for the warfighter. The security of the nation depends on interconnected systems, such as the power grid, telecommunications systems, social and organizational networks, economic and financial systems and command and control structures. These networks can suffer dramatic failures (examples include the Midwestern power grid outage and the increasingly mission-critical yet fragile internet infrastructure). Such failures can potentially be prevented or controlled through a fundamental, quantitative understanding of the intrinsic properties of networks, or more generally, any interconnected system. Deeper scientific foundations for what might be called "network understanding" will eventually generate dramatic new capabilities for the DoD while at the same time generating benefits for civilian applications. Overall, the program will provide vastly expanded power and improved interaction for a wide range of military tasks and environments.

(U) Research on machine intelligence over the last two decades has revealed that many reasoning problems are inherently computational complex, and in many cases, intractable. The Real-World Reasoning thrust (REAL) is developing foundational technologies, heuristic approaches, and tools necessary to enable effective, practical machine reasoning about increasingly complex, large-scale problems on time scales and with accuracies that will aid commanders and warfighters in assessing the consequences of specific actions and strategies, and predict future results. This research will push the envelope of deep-reasoning decision-making by systematically considering interactions among multiple teams of warfighters, robots and weapon systems in strategic settings where each team may have different or varying goals. The key technologies under investigation are effective, practical inferential reasoning in real-world situations with complexity and uncertainty; novel paradigms for learning from experience, events, and actions that affect the final outcome of a situation or scenario; integration of multiple reasoning paradigms; representation and reasoning with information that changes constantly over time; reasoning about the goals of other agents; pragmatic reasoning that uses appropriate default assumptions to respond intelligently; and appropriate metrics for measuring cognitive behavior and performance.

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(U) Program Plans:

- Develop new forms of human-computer interaction that enable humans and computers to work as synergistic teams. An initial suite of technologies has been developed and tested.
- Explore cognitive models for integrating users' natural communication modalities (e.g., spoken language, gesture, and gaze) for a new class of interfaces. Preliminary work on spoken language input and gesture has been done and tested for robustness.
- Develop adaptive multimodal processing techniques tailored to the user, task, and environment, assessing performance and usability advantages within multimodal systems.
- Develop a mixed-initiative multi-threaded task manager that is advisable by the user, able to alert the user to key activities and events, and able to be told limited forms of new knowledge.
- Establish multidisciplinary studies of large-scale interconnected systems drawn from the fields of information theory, complexity theory, adaptive systems, diffusion theory, group theory and social network analysis.
- Identify fundamental properties common across different types of networks and other distributed systems.
- Investigate the relationship between the statics and dynamics of networks, and relate these to important phenomena (such as tipping points) and properties (such as the resilience of networks to attacks and failures).
- Develop methods for combining statistical and knowledge-based reasoning and learning algorithms.
- Develop and demonstrate scalable high-performance reasoning techniques and knowledge representation methods that perform temporal reasoning, handle rapid changes in information, and deal with temporal static uncertainty.
- Develop innovative techniques for dramatically reducing the complexity and processing required for reaching conclusions in propositional logic systems.
- Evaluate algorithms to find the dominant plan and/or the Nash equilibrium solution from a given set of plans for a variety of reasoning tasks, such as effective coalition formation.
- Develop strategic reasoning tools that will aid decision-making in distributed environments, and will systematically incorporate information, incentives and goals in a complex multi-adversarial environment.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research				R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project ES-01				
COST (In Millions)	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Electronic Sciences ES-01	27.854	33.965	23.783	23.453	25.169	25.679	26.752	26.752

(U) Mission Description:

(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.

(U) Program Accomplishments/Planned Programs:

	FY 2004	FY 2005	FY 2006	FY 2007
University Photonic Opto-Centers	11.568	7.072	5.922	9.245

(U) This program is 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 include emitters, detectors,

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modulators and switches operating from infrared to ultraviolet wavelengths, and related heterogeneous materials processing and device fabrication technologies for realizing compact, integrated optoelectronic modules. The University Opto-Centers Phase II program will facilitate and enhance interaction between the developers of cutting edge photonic device technology in the industry and academic researchers that exploit these devices for novel applications. Industrial participants benefit by getting feedback from potential users of their device technology as well as by ensuring that the graduates are trained in the latest device technologies.

(U) Program Plans:

- Evaluate novel methods for the design, fabrication and demonstration of chip-scale modules that integrate photonic, electronic and MEMS based technologies.
- Characterize the impact of these new technologies on applications in the areas of bio-photonics, optically addressed memory and on-chip optical interconnects.
- Fabricate and test individual chip-level sub-assemblies for later use in prototype development.
- Design and fabricate prototype modules using the system-on-a-chip approach.
- Develop testbeds capable of fully measuring and characterizing the mixed technologies implemented in the chip-scale components.
- Evaluate the performance characteristics of the prototype modules and determine the highest payoff dual use development paths.
- Identify and enlist industrial participants.
- Develop a process for competitive selection of Phase II university participants.
- Identify a common set of photonic devices most widely used/requested and make them immediately available for experimentation.

	FY 2004	FY 2005	FY 2006	FY 2007
Semiconductor Technology Focus Centers	5.000	10.000	8.876	10.000

(U) The Semiconductor Technology Focus Center Research program concentrates on exploratory and fundamental semiconductor research efforts that solve the most critical, long-term scaling challenges in the fabrication of high performance complex integrated circuits. This program will develop new design and fabrication approaches and will demonstrate technologies for reaching nano-scale device dimensions and hyper-scale integrated circuits that will meet future military needs.

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(U) Program Plans:

- Develop efficient platform-based design methodologies and low latency interconnect technologies for complex integrated circuits that have application in high performance signal processing and communications systems.
- Develop methods for physics-based simulations of performance of deeply scaled switching device structures and circuit architectures.
- Develop the interface methodology for efficient handling and compilation of design object information for complex military integrated circuits.
- Develop circuit architectures that reduce long interconnects.
- Develop novel device fabrication and integration approaches for deeply scaled transistors and architectures for high performance mixed signal circuits for military needs.

	FY 2004	FY 2005	FY 2006	FY 2007
Molecular Photonics(MORPH) (formerly Supermolecular Photonics Engineering)	5.168	6.893	7.885	2.610

(U) Large dendritic and other highly branched organic molecules offer great potential for active photonic applications. Three-dimensional molecular structure and shape 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. This will allow more freedom to tailor electromagnetic response of individual molecules to achieve functionality not possible in semiconductors. 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.

(U) Program Plans:

- Model and simulate advanced structures for four classes of applications.
- Improve modeling capability for predicting macro functionality from nanostructure.
- Emphasize chemical synthesis.
- Address parameters such as thermal stability, environmental chemistry tolerance (O_2, H_20, etc) and photochemistry.

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- Fabricate initial devices; continue modeling maturation.
- Final material synthesis, prototype device fabrications, characterization and demonstration.

	FY 2004	FY 2005	FY 2006	FY 2007
Advanced Photonics Research	2.450	3.500	0.000	0.000

(U) Program Plans:
- Continue research in photonic composites and device fabrication.

	FY 2004	FY 2005	FY 2006	FY 2007
Photonics Technology Access Program (PTAP)	3.668	2.500	1.100	1.598

(U) The main goal of the Photonic Technology Access Project (PTAP) is to create a mechanism for providing the latest prototype optoelectronic devices and custom materials to systems researchers. The program seeks to build bridges between the device and systems research community, the university and industrial community and the teaching and research community.

	FY 2004	FY 2005	FY 2006	FY 2007
Nanophotonics Systems Fabrication	0.000	3.000	0.000	0.000

(U) Enhance nano-photonic systems fabrication capabilities for DoD by concentrating on unique technologies for photonic device fabrication, integration and packaging.

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	FY 2004	FY 2005	FY 2006	FY 2007
Repeatable & Robust Lithographic Processes	0.000	1.000	0.000	0.000

(U) Develop novel lithographic devices and new processes.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Materials Sciences MS-01	46.895	54.036	33.985	34.450	34.625	35.338	36.968	36.968

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

	FY 2004	FY 2005	FY 2006	FY 2007
Nanoscale/Bio-molecular and Metamaterials	7.845	14.051	11.000	11.450

(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 properties of materials. This includes efforts to develop the underlying physics for the behavior of materials whose properties have been engineered at the nanoscale (Metamaterials) level.

(U) Program Plans:

- Develop theoretical understanding and modeling tools for predicting novel metamaterial structures that exhibit superior microwave and magnetic properties for DoD electric drive and propulsion, power electronics, antenna, and radar applications.
- Develop algorithmic approaches for predicting properties and structure of nano-scale and meta-materials using first principles/quantum mechanical methods with higher accuracy and reduced computational complexity.
- Couple the algorithmic approaches to methods that extract parameters for simulation of materials at larger spatial scales while conducting experiments to verify/validate the predicted properties at all spatial scales.
- Explore fundamental behavior of nanostructured materials that display quantum and/or non-equilibrium behavior.

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- Develop theoretical advances to characterize the propagation of random effects through differential equation models of electromagnetic material systems to allow interpolation, extrapolation, and hybridization of solutions to known systems to closely related "perturbed" systems.
- Develop advanced image detector materials to instantly and simultaneously detect one structural (computed tomography) and two functional (position emission tomography and single photon emission tomography) images of medical and life science interest.
- Demonstrate materials capability to allow multimodal imaging system with two orders of magnitude increased scan speed and detection for ultra-rapid baggage screening and non-destructive testing and evaluation.
- Develop approaches for exploiting femtosecond laser pulses to generate multi-spectral imaging capable of examining nanostructured materials.

	FY 2004	FY 2005	FY 2006	FY 2007
Engineered Bio-Molecular Nano-Devices and Systems	5.200	10.985	10.985	11.000

(U) This program seeks to develop and demonstrate engineered bio-molecular nano-scale devices that 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 100X) reduction in the time required for analysis and identification of known and unknown (engineered) molecules.

(U) Program Plans:

- Engineer hybrid biological/inorganic device architectures that optimize compatibility and information transfer between biological and non-biological materials with single molecule sensitivity.
- Develop new and innovative technologies in the areas of device architecture, design, interconnection, fabrication and integration of organic and inorganic materials to enable measurement of time constants of single molecule events.
- Develop techniques to perform direct, dynamic, stochastic and combinatorial analysis of bio-molecular signals in order to characterize unique molecular signatures based on such analysis (i.e., automatic recognition) of various biological/chemical targets.

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	FY 2004	FY 2005	FY 2006	FY 2007
Spin Dependent Materials and Devices	13.600	6.000	12.000	12.000

(U) The 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. Not only will this class of electronics lead to novel and faster electronic devices, but it will also serve as one of the key technology enablers for quantum communications and quantum computation.

(U) Program Plans:

- Demonstrate a room temperature spin light emitting diode (spin LED).
- Demonstrate a spin transistor with significant gain.
- Demonstrate spin coherent optical devices operating at speeds approaching a terahertz.
- Demonstrate a phase coherent and phase controlled device operating above 10 GHz.
- Demonstrate a scaleable spin-based implementation for quantum logic gates.
- Scale magnetic random access memory down into the few nanometer bit size by replacing magnetic field switching with spin momentum transfer switching.
- Develop new storage class memories with 100 – 1000 times the density of MRAM, DRAM or FLASH using magnetic domain walls as the storage media and spin momentum transfer as the read and write protocol.
- Demonstrate highly tunable, coherent microwave and millimeter wave radiation with on-chip nanoscale devices using spin electronics.

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	FY 2004	FY 2005	FY 2006	FY 2007
Spin Electronics	12.750	16.200	0.000	0.000

(U) Program Plans:
- Continue to explore new directions in spin electronics to determine areas important for continued DoD investment.
- Continue exploration of the benefits of using the spin degree of freedom in organic electronics.
- Continue to study spin dynamics in nanostructures.
- Continue exploring new materials and structures that exhibit spin dependent behavior.

	FY 2004	FY 2005	FY 2006	FY 2007
Joint Collaboration on Nanotechnology	1.700	0.000	0.000	0.000

(U) Program Plans:
- Continued to investigate the potential enabling impact of recent nanotechnology material developments in biotechnology applications.

	FY 2004	FY 2005	FY 2006	FY 2007
Joint Collaboration on Nanotechnology and Biosensors	3.000	0.000	0.000	0.000

(U) Program Plans:
- Funded a consortium of university researchers that investigated the potential application of nanotechnology for advanced biosensor developments.

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	FY 2004	FY 2005	FY 2006	FY 2007
Nano- and Microelectronics	2.800	0.000	0.000	0.000

(U) This research provided the tools for developing molecular electronics technologies to enable construction of electronic circuits at the nanometer-scale for computation.

(U) Program Plans:
- Demonstrated computing with molecular-scale structures – i.e., nanometer-scale structures.
- Characterized and organized nanometer-scale materials.

	FY 2004	FY 2005	FY 2006	FY 2007
Molecular Electronics	0.000	1.900	0.000	0.000

(U) Program Plans:
- Provide tools for developing molecular electronics technologies to enable construction of electronic circuits at the nanometer-scale for computation. Research focuses on the simulation and direct-write fabrication of room temperature single electron transistors using focused ion beam instrumentation.

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	FY 2004	FY 2005	FY 2006	FY 2007
Comparative Genomics for National Security Goals	0.000	3.000	0.000	0.000

(U) Program Plans:
- Develop new approaches to examine prognostic epidemiology using comparative genomics.

	FY 2004	FY 2005	FY 2006	FY 2007
Material Characterization and Meteorology Center	0.000	0.500	0.000	0.000

(U) Program Plans:
- Develop tools and methods for characterization of materials.

	FY 2004	FY 2005	FY 2006	FY 2007
Space Based Active Sensors	0.000	1.400	0.000	0.000

(U) Other Program Funding Summary Cost:

- Not Applicable.