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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, R-1 #2

COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	62.940	108.806	121.003	117.398	118.300	120.100	126.100	131.100	Continuing	Continuing
Bio/Info/Micro Sciences BLS-01	0.000	0.000	65.000	58.250	55.775	55.000	60.000	65.000	Continuing	Continuing
Information Sciences CCS-02	17.962	34.777	15.303	17.000	17.925	22.700	23.200	23.200	Continuing	Continuing
Electronic Sciences ES-01	13.696	21.371	19.743	19.370	20.547	23.347	23.847	23.847	Continuing	Continuing
Materials Sciences MS-01	31.282	52.658	20.957	22.778	24.053	19.053	19.053	19.053	Continuing	Continuing

(U) <u>Mission Description:</u>

(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 sciences, and attempt to exploit these advances in the development of new technologies and systems of interest to the DoD. The project will apply 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 Futures; Biological Adaptation, Assembly, and Manufacturing; and Nanostructure in Biology. Although this is a new project, the programs funded within it are not new starts. These efforts were initiated in FY 2001 and prior but were grouped together and separately funded to ensure the visibility of this important initiative.

(U) The Information Sciences project supports basic scientific study and experimentation in information sciences technology areas 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. This project will also explore

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scientific study and experimentation emphasizing biological software, computations based on biological materials, physical interfaces between electronics and biology, and interactive biology. The Bio/Info/Micro Sciences efforts previously budgeted in this project transfer to Project BLS-01 in FY 2002.

(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) a substantial increase 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 biomolecular materials and interfaces; materials and measurements for molecular-scale electronics; spin-dependent materials and devices; and novel propulsion concepts.

(U) Program Change Summary: (*In Millions*)	**FY2000**	**FY 2001**	**FY 2002**
Previous President's Budget	67.608	90.415	94.263
Current Budget	62.940	108.806	121.003

(U) Change Summary Explanation:

FY 2000	Decrease reflects SBIR reprogramming and minor program realignments.
FY 2001	Increase reflects net effect of congressional adds for Advanced Photonics Research, Nanoelectric Science and Technology, High Speed Computer Information Systems Bandwidth Research; Spectral Hole Burning applications; Wireless Technology Research; and Spin Electronics. This increase is partially offset by the Section 8086 reduction and the government-wide rescission.
FY 2002	Increases reflect planned expansion of efforts funded in the Bio/Info/Micro Systems project (BLS-01). These programs are an outgrowth of initiatives first funded in CCS-02 in FY 2001.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Bio/Info/Micro Sciences BLS-01	0.000	0.000	65.000	58.250	55.775	55.000	60.000	65.000	Continuing	Continuing

(U) Mission Description:

(U) This project will explore and develop the intersections 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 will draw upon the 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. New capabilities and methods for performing complex military operations will arise by applying lessons learned from the models provided by living systems that function and survive in a complex environment and adapt to changes in that environment. The combination of biological science and technology offers an avenue into the understanding and development of systems that are capable of complex, robust, and adaptive operations using fundamentally unreliable components. The tools developed will enable radically new command capabilities to deal with increased complexity in warfare, while addressing the increasing demands being placed on warfighters. This project will explore the information architectures that enable key communications between these biological elements and the physical basis for predicting structural and functional relationships, as well as the application of biological principles to the advancement of information and physical sciences. A number of key focus areas have been identified including: multidisciplinary programs in BioComputational Systems; Simulation of Bio-Molecular Microsystems; Bio Futures; Biological Adaptation; Assembly and Manufacture; and Nanostructure in Biology. A component these programs offer will be the identification, development and demonstration of new mathematical algorithms that enable the representation of biological systems and the identification of the emergence of biologically inspired algorithms for these complex, non-linear problems.

(U) The BioComputation Systems component will explore and exploit computing mechanisms in the bio-substrate for a variety of applications of interest to the DoD. The program seeks to create accurate and validated models of computation and information processing across the spectrum of biological systems, from the molecular to organismal level. The efforts will encompass the miniaturization of biocomputation hardware to produce these systems. The program will investigate biological computing mechanisms such as those found within DNA, biological cells like those of the immune system, between cells in tissues, within individual organisms, and social groups of organisms such as swarms or schools. These biological systems will be explored and manipulated to discover the informational and physical architectures that enable the solution of hard computational problems as well as for massive, but efficient storage and recall. This effort will also develop and apply informational architectures

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such as language technology tools to critical biological problems of gene identification within sequences of biological elements such as base pairs, three-dimensional structure prediction from sequences, and discovery of the circuits within which proteins interact to complete biological functions. This program seek to improve time efficiencies and manufacturing capabilities of biological systems production hardware by miniaturizing it to a circuit board size system. In addition, the program will begin leveraging discovered bioinformatics applications of tools and methods to improve human systems engineering processes such as automatic understanding and translation within human systems and effective man machine interfaces.

(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. SIMBIOSYS will explore fundamental properties and compatibility of biological elements at surfaces 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. Specifically the SIMBIOSYS program will develop methods and tools to simulate and design Bio-Molecular Microsystems with a high degree of multi-disciplinary integration.

(U) The Bio Futures program will support scientific study and experimentation, emphasizing biological software, computation based on biological materials, physical interfaces between electronics and biology, and interactive biology. It will apply information technology to accelerate the analysis and synthesis of biological processes. The seamless integration of information technology and biological processes will provide the ability to exert computational control over biological and chemical processes. The Bio Futures program will also support the development of genomics-based platforms for enhancing the capabilities of biological systems to manufacture, sense, or compute. Genomics–based platforms will enable rational medical drug discovery and broadspectrum antibiotics discovery for pathogens confronting the warfighter.

(U) The Biological Adaptation, Assembly and Manufacturing program will examine the structure, function, and informational basis for biological system adaptation, assembly and manufacturing of complex systems. In the adaptation element, 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 labile systems of Defense needs (such as blood or other therapeutics). This will be explored using bioinformatics tools to characterize the differential gene expression that produces tolerance to highly stressful and/or lethal environmental conditions. These “stress gene” products will be analyzed for their ability to improve the survival of living cells and tissues. Tools of metabolic engineering will be applied to afford stability in labile systems of interest. The assembly and manufacturing element of this component will explore

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the fundamental developmental and fault tolerance present in biological systems in order to assemble and manufacture complex physical and multi-functional systems. Initial activities in this area will focus at the biomolecular scale and will examine nanoscale biomolecular networks involved with assembly and manufacturing in biological systems (e.g. bone, shell, skin). The transfer of materials within these systems in nanofluidic biomolecular network systems will be explored. The program will exploit the fundamental principles of physical work from biological principles that derive from the investigation of the intersection between physical force dynamics of biological systems and the application of new computational and information processing tools to explore biomechanics. Further activity in this area will investigate the communication between adaptive elements within biological systems 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 highly adaptive, non-linear robust systems.

(U) The Nanostructure in Biology program will investigate the nanostructure properties of biological materials in order to better understand their behavior and thereby accelerate their exploitation for Defense applications. The tools and approaches developed under this program will have a significant impact in a variety of critical, non-biological Defense technologies that rely on phenomena occurring at the nanoscale level. For example, The Molecular Observation, Spectroscopy, and Imaging using Cantilevers (MOSIAC) program will develop new instrumentation computational tools and algorithms for real-time atomic level resolution 3D static or dynamic imaging of molecules and nanostructures. This new information about biomolecules will provide important new leads for the development of threat countermeasures, biomolecular sensors and motors, and molecular interventions to enhance and improve human performance. This tool will help with detailed knowledge of doping profiles and defects. It might be possible to use these techniques to measure and control individual atoms or spins. Another aspect of this program will examine the use of nanostructured magnetic materials to understand and manipulate cells and tissues, enhancing their capabilities to serve as sensors and/or regulatory pathways. The Bio-Magnetics Interfacing Concepts (Bio-MagIC) program will explore nano-scale magnetism as a novel transduction mechanism for the detection, manipulation and actuation of biological function in cells and single molecules. The core technologies to be developed will focus on the many technical challenges that must be addressed in order to integrate nano-scale magnetism with biology at the cellular and molecular level, and to ultimately detect and manipulate magnetically 'tagged" bio-molecules and cells. These programs will present unprecedented new opportunities to exploit a wide range of bio-functionality for a number of DoD applications including chemical and biological sensing, diagnostics and therapeutics.

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(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Not Applicable.

(U) FY 2001 Plans:

- Not Applicable.

(U) FY 2002 Plans:

- BioComputational Systems. ($ 27.000 Million)
  - Initiate the investigation of scalable computing mechanisms using DNA manipulations.
  - Investigate the use of biomolecular (e.g., DNA) and other biological elements (biochemical pathways, cells) as an ultra-compact, massive storage mechanism with tagging and associative search capability.
  - Implement methods for creating programmable two-dimensional nano-structures based on DNA fragments.
  - Explore the design of multi-state bio-based synthetic logic circuits for monitoring and reporting states as well as for process control.
  - Initiate open source development of spatio-temporal computational models and software of internal cellular processes.
  - Specify architecture for software development for creation of Bio-SPICE: Simulation Program for Internal Cellular Processes.
  - Initiate software integration of components leading to Bio-SPICE and its ongoing iterated development.
  - Initiate experiments at the cellular level to evaluate, confirm and validate models of intra-cellular processes of interest to DoD such as host-bacterial engagements, and processes such as molecular level rhythms that may impact on warfighter performance.
  - Initiate investigation of a biologist friendly cellular process simulation tool, including database definitions and user interface tools.
  - Examine computational abilities of networks of cells and organized groups such as schools or swarms.
  - Examine control methods of communication and regulation of activities in cells and organized groups of cells or organisms, such as colonies or mats.

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- Develop and test algorithms and design tools for the virtual representation and manipulation of dynamic biological systems.
- Develop preliminary miniaturized hardware designs for microchemical oligonucleotide manufacture, manipulation and amplification proof of principle brassboards.
- Initiate studies on error correction and optimal information encoding of microchemical oligonucleotides.

• Simulation of Bio-Molecular Microsystems (SIMBIOSYS). ($ 14.000 Million)
  - Engineer biological circuits and architectures that optimize compatibility and information transfer between biological and non-biological materials to improve the interaction and integration of biological elements with synthetic materials in the context of microsystems.
  - Develop methods to characterize interfaces that allow one- and two-way communications, smart control, longevity and stability.
  - Create instrumentation and tools that will improve experimental validation of models that explore biological systems at interfaces.
  - Develop and validate phenomenological models for a range of signal transduction processes.
  - Develop data and models on electrokinetic transport and surface tension driven flows in microsystems.
  - Investigate novel hybrid macro-molecular devices that form specific and controlled transducing functions at the molecular scale.

• Bio Futures. ($ 8.619 Million)
  - Demonstrate high-throughput manipulation and interrogation of biochemical and molecular features in single cells.
  - Demonstrate informatics frameworks for integrating imaging and biochemical data from single cells.
  - Demonstrate the application of novel nano-devices to measure, manipulate and control cells, tissues, and biomolecules.
  - Exploit nanoscale fluidic phenomena to achieve control of molecular level activity interrogation and control.
  - Develop nanofluidic interfaces for selective transport of multi-scale bimolecules.

• Biological Adaptation, Assembly and Manufacture. ($ 5.381 Million)
  - Identify and optimize strategies for manipulating cell and tissue survival in response to exogenous stimuli including stressful conditions.
  - Examine pluripotential and totipotential cells for principles of assembly, manufacture and long term survival.
  - Define the engineering parameters for biomechanical systems; develop computational models of biomechanics that can be used to design and engineer new mechanical systems that mimic biomechanical system performance

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- Develop mathematical tools to reduce dimensionality of biomechanical forces involved in biological force production from biological motors, cells, tissues and appendages.
- Examine methods of control for directed cell proliferation and cellular stasis at the tissue and organismal level.

• Nanostructure in Biology. ($ 10.000 Million)
  - Explore novel techniques for atomic resolution three dimensional non-destructive imaging of biomolecules.
  - Form multidisciplinary teams to build high sensitive magnetic resonance for microscopes.
  - Demonstrate a scalable process for producing bio-compatible magnetic nanoparticles (10-100 nm diam.) with table and reproducible magnetic properties and less than five percent variation in nanoparticle diameter.
  - Demonstrate a biocompatible magnetic sensor capable of detecting a single magnetic nanoparticle with diameter less than 100nm.
  - Identify and model specific cellular signaling pathways to be investigated using magnetic actuation.

(U) <u>Other Program Funding Summary Cost:</u>

• Not Applicable.

(U) <u>Schedule Profile:</u>

• Not Applicable.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Information Sciences CCS-02	17.962	34.777	15.303	17.000	17.925	22.700	23.200	23.200	Continuing	Continuing

(U) <u>Mission Description:</u>

(U) This project supports scientific study and experimentation that is the basis for more advanced knowledge and understanding in the information sciences technology areas related to long-term national security requirements such as computational models and new mechanisms for performing computation and communication. This project is also exploring innovative approaches to the composition of software and novel human computer interface technologies.

(U) Ubiquitous Computing and Human Computer Interfaces will develop information technologies for an environment where the warfighter is surrounded by computers that interact with them in mobile, intuitive fashion and enable collaborations as well as intelligent exchange of information in a seamless fashion. Architectures for nomadic software, redesigns of classical notions of computer operating systems and secure information exchange over insecure channels are some of the technical challenges in this area. Database currency and management of dynamically changing worldviews is another important area of research in pervasive computing. Ubiquitous Computing will explore new man-machine interaction paradigms, based on implicit interaction where the human's intent is inferred and used to drive the interaction. This will create a more naturalistic interaction and greatly reduce the overhead for the user.

(U) High-Speed Computer Information Systems Bandwidth and Wireless Technology Research is focused on improving the end-computer-system bandwidth by an order-of-magnitude to enable true gigabit to terabit information transfer. Removing the bottleneck that lies within the end systems will be investigated. Some of the approaches to be explored include development of next-generation switched system architecture and distributing the CPU-intensive functions to preferral high-speed modules. This is a one-year effort funded in FY 2001.

(U) In the area of Bio Futures, the combination of biology with information technologies and physical systems will open a new field of incredible potential. These technical fields reached a capability level where the combination can enable both fundamental and applications breakthroughs. Progress in biology will be greatly aided by the ability to understand and manipulate the massive data inherent in living systems. Microelectronics and sensors reached a level of systems sophistication and miniaturization that now can directly interface with biological cells. The

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fields of biological science and technology offer an understanding of systems complexity and robust operation using fundamental unreliable components, an understanding that will enable new approaches for information technology, computers and electronics.

(U) The Bio Futures effort supports scientific study and experimentation, emphasizing biological software, computation based on biological materials, physical interfaces between electronics and biology, and interactive biology. It will apply information technology to accelerate the analysis and synthesis of biological processes by applying statistical language modeling tools to the problems of rapid bio-sequencing. The seamless integration of information technology and biological processes will provide the ability to exert computational control over biological and chemical processes and accelerated discovery of gene expression and protein-protein interactions. The applications of this will be to develop techniques using information theory for rational medical drug discovery and broad-spectrum antibiotics discovery for pathogens confronting the warfighter. Another area of exploration, the Simulation of Bio-Molecular Microsystems (SIMBIOSYS), will develop and demonstrate the capability to stimulate and design chip-scale bio-molecular microsystems with a high degree of multi-disciplinary integration. Both Bio Futures and SIMBIOSYS transfer to the new Bio/Micro/Info Sciences Project (BLS-01) in FY 2002.

(U) Despite recent advances in automatic speech recognition (ASR), their utility is restricted to small to medium vocabularies, noise free environments and single speakers at a time. Speech Recognition in Noisy Environments research supports research on omnipresent automatic recognition and synthesis from multiple input modalities that will enhance the ability of a computer system to correctly interpret the intent of the target speaker in a variety of environments. This technology includes the fusion of gaze, gesture, lip reading, and alternative speech detection through physiological micro-sensors and airborne acoustic systems. The research will be evaluated by a series of performance tests conducted on data sets that are created from various meeting environments. These meeting environments include such challenging speech conditions as sloppy speech, noisy speech, cross talk and speech variability due to changing emotional state and stress.

(U) <u>Program Accomplishments and Plans:</u>

(U) <u>FY 2000 Accomplishments:</u>

- Biological and Amorphous Computing. ($ 9.595 Million)
  - Evaluated alternative approaches to DNA-based computing and identified the most promising research opportunities for enhancement and acceleration.
  - Explored mechanisms for sequencing of DNA-based computations.

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- Investigated the use of game theory, probabilistic methods, and amorphous computing in information technology (IT), for use in decision aids and time critical systems.
- Engineered complex artificial systems and explored biological systems across different size scales using multi-disciplinary approaches.
- Explored biologically inspired algorithms and models for computation.
- Investigated novel approaches to real-time biological instrumentation in support of interactive biology, including development of minimally invasive imaging tools for monitoring the state of ongoing biological experiments.

• Ubiquitous Computing and Human Computer Interfaces. ($ 8.367 Million)
  - Designed and implemented a prototype interactive programming environment for pervasive computing.
  - Developed architectural design for ubiquitous computing using mobile devices with multi-modal data entry.
  - Created a prototype Information Grid Room (IGR) that provides invisible computing and data storage for a single user.

(U) <u>FY 2001 Plans:</u>

• Ubiquitous Computing. ($ 6.422 Million)
  - Develop representation and abstraction man-machine algorithms for inferred interaction.
  - Demonstrate the first version of a small footprint operating system in an operational environment.
  - Demonstrate self-organization of small number of heterogeneous devices.
  - Demonstrate policy negotiation for accommodating several users in a ubiquitous computing environment.

• Bio Futures. ($ 26.270 Million)
  - Biological and Amorphous Computing.
    - - Demonstrate real-time multi-sensor imaging of cell processes in support of interactive biology.
    - - Establish focused research initiatives at the interface between biology, engineering and information sciences.
    - - Demonstrate use of high resolution imaging technology and signal transduction to affect interactive control over simple biological systems.

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- - Evaluate alternative approaches to the implementation of game theory, probabilistic methods, amorphous computing in decision tools and software development.

– Bio:Info: Physical Systems Interface.
  - - Explore fault tolerant hardware architectures, software techniques with the ability to self-heal and reprogram adaptively.
  - - Demonstrate modeling and control of genetic circuits, expression of proteins, protein-protein interaction and cellular function for rational medical drug design.
  - - Develop new hybrid devices combining biological and artificial components scaling from molecular-scale to population level.
  - - Create biologically inspired algorithms and models for computation, possibly including systems of hybrid devices.
  - - Apply developments in biology, information science and materials science to dramatically improve the interactions of humans and systems.
  - - Determine feasibility of reducing oligonucleotide production, manipulation, and amplification to micro-chemical miniaturization processes and initiate development of process model.
  - - SIMBIOSYS: Develop and validate models, phenomenological relationships and scaling laws for a range of bio-molecular recognition processes in microsystems.

- High-Speed Computer Information Systems Bandwidth. ($ 1.489 Million)
  – Demonstrate next-generation TCPIP protocol enhancements and protocol tuning tools to enable high-speed computer communications interconnect.

- Wireless Technology Research. ($ 0.596 Million)
  – Develop technology enabling orders of magnitude improvement in reliability and performance in military wireless networks through joint adaptation of network protocols and wireless transmission methods including coding, modulation, and range.
  – Investigate information assurance methods for miniaturized wireless sensor networks.

(U) <u>FY 2002 Plans:</u>

- Ubiquitous Computing. ($ 8.322 Million)
  – Deliver architecture for persistent, distributed storage in an untrusted infrastructure.

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- Demonstrate delivery of information based on automatic situation recognition.
- Implement baseline ubiquitous computing architecture for experimentation.
- Demonstrate use of audio and tactile channels for delivering situational awareness information.
- Demonstrate the scalability of the small footprint operating system to less than ten heterogeneous devices.

- Speech in Noisy Environments (SPINE). ($ 6.981 Million)
  - Incorporate core Automatic Speech Recognition (ASR) algorithms into new robust ASR prototype.
  - Integrate state-of-the-art multi-modal input devices into defined multi-modal ASR protocol stack.
  - Establish data-type standards for multi-modal input devices (in support of plug-and-play and system independent design).
  - Start feasibility test on the use of robust ASR prototype in a simple maintenance task.
  - Conduct first evaluation of group speech discussion software; approve protocol and metric for second challenge meeting task evaluation.
  - Conduct initial demonstration and evaluation to show that an over-abundance of sensor information can be transformed into actionable information.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Electronic Sciences ES-01	13.696	21.371	19.743	19.370	20.547	23.347	23.847	23.847	Continuing	Continuing

(U) <u>Mission Description</u>:

(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 research addressing 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 for nanometer-scale mechanical, electrical and fluidic analysis offer new approaches to integration, testing, controlling, manipulating and manufacturing nanometer-scale structures, molecules and devices.

(U) This project is also concerned with coupling university based engineering research centers of excellence with appropriate industry groups to conduct research leading to development of advanced optoelectronic components. Such components will be critical to enhancing the effectiveness of military platforms that provide warfighter comprehensive awareness and precision engagement, and will contribute to the continued advancement of Next Generation Internet capabilities. Topics to be researched include 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.

(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 Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Mechanical Electronics. ($ 1.832 Million)
  - Demonstrated the properties for mechanical switches that included device speed and current density scale and size, hysteretic behavior for non-volatile memory applications and reduced threshold switching voltage to below 10V.

- Terahertz Technology. ($ 3.297 Million)
  - Continued to exploit the terahertz region of the electromagnetic spectrum by investigating the best semiconductor approaches to sources and detectors, identifying mission critical operation.
  - Investigated the feasibility of integrating these components to form a range of compact subsystems for applications in space-based communications, remote sensing, covert communication and chem-bio detection.

- Microinstruments. ($ 3.076 Million)
  - Researched new technology for diagnostic instruments to support, maintain and service the warfighter and military platforms.
  - Investigated new technology concepts that support high volume/low cost wearable and hand-held diagnostic instruments.
  - Explored microinstruments “on-a-chip” concepts that integrate sensors, electronics, storage, display and actuation.
  - Evaluated microinstruments that include fluid dispensing, fluid sensing, and fluid identification important for "in-the-field" medical, chemical/biological and equipment diagnostics and repair.
  - Demonstrated a patterning microinstrument that writes a pattern of array of 50nm minimum – feature-size bits or pixels at a rate of $6cm^2$/sec over an area of $1cm^2$.

- University Opto-Centers. ($ 5.491 Million)
  - Established university opto-centers focused on creating new capabilities for the design, fabrication and demonstration of chip-scale modules that integrate photonic, electronic, and Microelectromechanical Systems (MEMS) based technologies.
  - Identified university technology research goals and modality for facilitating access by industry to these technologies.

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(U) FY 2001 Plans:

- Terahertz Technology. ($ 4.566 Million)
  - Demonstrate, for the terahertz spectral region, the best semiconductor quantum-well approaches to sources.
  - Demonstrate semiconductor quantum-well detectors.
  - Identify system requirements to achieve space communications, upper-atmosphere imagery and close-operations covert communications.

- University Opto-Centers. ($ 13.826 Million)
  - Demonstrate initial chip-scale integrated photonic, electronic and MEMS modules.
  - Identify the most compelling DoD module applications and measure level of industry commitment to adopt chip-scale integration approach.

- Advanced Photonics Research. ($ 2.979 Million)
  - Develop photonic composite material modeling, design, growth, analysis, processing and device fabrication.

(U) FY 2002 Plans:

- Terahertz Technology. ($ 2.281 Million)
  - Demonstrate compact sources and detectors capable to operate between 0.2 – 10 terahertz (THz).
  - Demonstrate terahertz, short-range detection system.
  - Assess experimental component performance and compare against system requirements for space communications, upper-atmosphere imagery and close-operations covert communications.

- University Opto-Centers. ($ 11.407 Million)
  - Evaluate novel methods for the design, fabrication and demonstration of chip-scale modules that integrate photonic, electronic and MEMS based technologies.

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- 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.

- Semiconductor Technology Focus Center. ($ 6.055 Million)
  - 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.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- 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 MS-01					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Materials Sciences MS-01	31.282	52.658	20.957	22.778	24.053	19.053	19.053	19.053	Continuing	Continuing

(U) <u>Mission Description:</u>

(U) This project is concerned with fundamental research leading to the development of high power density/high energy density mobile and portable power sources; processing and design approaches for nanoscale and/or biomolecular materials and interfaces; materials and measurements for molecular-scale electronics; a new class of semiconductor electronics based on the spin degree of freedom of the electron, in addition to (or in place of) the charge; and novel methods for reducing drag in future generations of high-speed ships. Follow-on activities for the Molecular Electronics program are funded in the Beyond Silicon project (MPT-08) under the Materials and Electronics Technology Program Element (0602712E) beginning in FY 2002. Similarly, Drag Reduction Technology development has matured and is funded in the Naval Warfare Technology project (TT-03) under the Tactical Technology Program Element (0602702E) in FY 2002.

(U) <u>Program Accomplishments and Plans:</u>

(U) <u>FY 2000 Accomplishments:</u>

- Portable Power. ($ 6.400 Million)
  - Designed, built and tested novel portable power sources that operate directly on logistics fuels.
  - Demonstrated a small (~50W) proton exchange membrane fuel cell operating on several novel hydrogen sources.
  - Demonstrated the operation of a portable direct methanol fuel cell.

- Nanoscale/Biomolecular Materials. ($ 9.233 Million)
  - Explored novel processing schemes for the formation of nanoscale/biomolecular and spin-dependent materials, interfaces, and devices.
  - Explored the capabilities of quasicrystals, amorphous metals, metamaterials, carbon nanotubes, quantum dots, and other nanostructured/biomolecular materials for enhancing the structural and functional performance of DoD systems.

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- Molecular Electronics. ($ 9.049 Million)
  - Demonstrated that molecules can be chemically tuned into a desired electronic functionality.
  - Fabricated nano-wires that are electrically conductive and can be assembled into rows or columns of wires via self-assembly.
  - Demonstrated that molecular and/or nanostructured materials can perform a storage function that can be driven from one state to another by an external signal.

- Advanced Drag Reduction (Fast Ship). ($ 3.000 Million)
  - Conducted integrated hydrodynamic model development at multiple scales to provide foundational theory for quantitative drag prediction and drag reduction prediction.
  - Commenced laboratory-scale calibration and confirmation testing of initial model predictions.

- Nanoelectric Research. ($ 1.900 Million)
  - Continued molecular and quantum-dot cellular automata nanoelectric research.

- Spectral Hole Burning. ($ 1.700 Million)
  - Investigated the applications of spectral hole burning.

(U) **<u>FY 2001 Plans:</u>**

- Nanoscale/Biomolecular Materials. ($ 9.703 Million)
  - Demonstrate enhanced performance from materials and processes incorporating nanostructured components.
  - Demonstrate the use of quantum chemistry for the theoretical design of new nanoscale/biomolecular/multifunctional materials and structures.
  - Explore the interface between biological systems and abiotic surfaces and materials.

- Spin-Dependent Materials and Devices. ($ 12.800 Million)
  - Demonstrate spin-polarized transport across ferromagnetic/semiconductor interfaces.
  - Optimize spin lifetime in semiconductor structures.

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- Demonstrate spin light emitting diode (spin-LED) and spin field effect transistor (spin-FET).

- Spin Electronics. ($ 10.000 Million)
  - Start multidisciplinary efforts to exploit the advantages of nanotechnology in spin electronics (spintronics).

- Molecular Electronics. ($ 9.300 Million)
  - Demonstrate that molecules and/or nanoparticles can self-assemble into functional, regular patterns.
  - Build and test a minimum 16-bit functional, reversible molecular memory sub-unit.
  - Build and test room temperature scalable logic gates using molecules.

- Advanced Drag Reduction (Fast Ship). ($ 6.555 Million)
  - Complete integrated hydrodynamic model development at multiple scales.
  - Complete laboratory-scale calibration and confirmation testing of initial model predictions.
  - Develop model-based performance predictions of different potential drag reduction techniques.
  - Confirm drag reduction performance predictions from laboratory-scale testing.

- Nanoelectric Research. ($ 2.500 Million)
  - Continue molecular and quantum-dot cellular automata nanoelectric research.

- Spectral Hole Burning. ($ 1.800 Million)
  - Continue investigation of the applications of spectral hole burning.

(U) **FY 2002 Plans:**

- Nanoscale/Biomolecular and Metamaterials. ($ 6.237 Million)
  - Develop approaches for synthesis of nanoscale/biomolecular materials based on encoded combinatorial synthesis of polymers.
  - Develop techniques for transferring information between cells and abiotic materials and surfaces.
  - Develop theoretical understanding of wave propagation in “left-handed” metamaterials.

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- Optimize processing schemes for engineering metamaterials with enhanced electromagnetic properties.
- Model non-linear response of rectifying metamaterials.
- Explore magnetism as a novel transduction and actuation mechanism for bio-chemical sensing.
- Develop approaches for predicting properties and structure of nanoscale and metamaterials using first principle/quantum chemical models.

- Spin-Dependent Materials and Devices. ($ 14.720 Million)
  - Demonstrate near room temperature spin light-emitting diode (spin-LED).
  - Demonstrate spin coherent optical modulators and switches operating at frequencies approaching a teraHertz.
  - Demonstrate an optically excited spin phase-logic device operating in the gigaHertz frequency range with very low dissipation.
  - Demonstrate conversion of optical quantum bit (qubit) into spin quantum bit.

(U) <u>Other Program Funding Summary Cost:</u>

- Not Applicable.

(U) <u>Schedule Profile:</u>

- Not Applicable.