Department of Defense FY 2003 Budget Estimate

Feburary 2002

RESEARCH, DEVELOPMENT, TEST AND EVALUATION, DEFENSE-WIDE

Volume 1 Defense Advanced Research Projects Agency

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FY 2003 RDT&E PROGRAM EXHIBIT R-1

APPROPRIATION: 0400D Research, Development, Test & Eval, Defwide Date: FEB 2002

Line No	Program Element Number	Item	Act	FY 2001 (Thousands of Dollars)	FY 2002 (Thousands of Dollars)	FY 2003 (Thousands of Dollars)	SEC
2	0601101E	Defense Research Sciences	1	99,647	142,303	175,646	U
		Basic Research		**99,647**	**142,303**	**175,646**	
9	0602110E	Next Generation Internet	2	14,461			U
14	0602301E	Computing Systems and Communications Technology	2	310,496	358,494	424,940	U
15	0602302E	Embedded Software and Pervasive Computing	2	47,876	65,561	60,000	U
16	0602383E	Biological Warfare Defense	2	146,216	146,680	133,000	U
18	0602702E	Tactical Technology	2	210,790	164,056	180,952	U
19	0602708E	Integrated Command and Control Technology	2	39,565			U
20	0602712E	Materials and Electronics Technology	2	255,026	344,554	440,500	U
		Applied Research		**1,024,430**	**1,079,345**	**1,239,392**	
36	0603285E	Advanced Aerospace Systems	3	38,093	153,700	246,000	U
45	0603739E	Advanced Electronics Technologies	3	213,379	199,564	150,400	U
48	0603760E	Command, Control and Communications Systems	3	129,162	115,149	130,101	U
49	0603762E	Sensor and Guidance Technology	3	138,508	192,095	224,000	U
50	0603763E	Marine Technology	3	25,290	36,497	33,000	U
51	0603764E	Land Warfare Technology	3	130,610	153,067	162,100	U
52	0603765E	Classified DARPA Programs	3	96,716	139,895	275,899	U
		Advanced Technology Development		**771,758**	**989,967**	**1,221,500**	
103	0605114E	BLACK LIGHT	6	4,940	5,000	5,000	U
113	0605502E	Small Business Innovative Research	6	42,363			U

Defense Adv Research Projects Agcy
FY 2003 RDT&E PROGRAM

EXHIBIT R-1

APPROPRIATION: 0400D Research, Development, Test & Eval, Defwide

Date: FEB 2002

Line No	Program Element Number	Item	Act	FY 2001	FY 2002	FY 2003	SEC
				Thousands of Dollars			
121	0605898E	Management Headquarters (Research and Development)DARPA	6	32,544	36,102	43,572	U
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		RDT&E Management Support		**79,847**	**41,102**	**48,572**	
124	0909999E	Financing for Cancelled Account Adjustments	6	1,000			U
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		RDT&E Management Support		**1,000**			
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		Total Defense Adv Research Projects Agcy		**1,976,682**	**2,252,717**	**2,685,110**	

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
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 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	99.647	142.303	175.646	175.887	176.514	179.118	179.755	Continuing	Continuing
Bio/Info/Micro Sciences BLS-01	0.000	65.000	90.000	109.336	119.979	134.586	135.310	Continuing	Continuing
Information Sciences CCS-02	29.348	12.303	28.000	21.873	19.831	14.844	14.815	Continuing	Continuing
Electronic Sciences ES-01	22.488	25.943	20.000	19.879	16.873	14.844	14.815	Continuing	Continuing
Materials Sciences MS-01	47.811	39.057	37.646	24.799	19.831	14.844	14.815	Continuing	Continuing

(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 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; Nanostructure in Biology; and Brain Machine Interface.

(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) 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, interfaces and microsystems; materials and measurements for molecular-scale electronics; spin-dependent materials and devices; and novel propulsion concepts.

(U) Program Change Summary: (*In Millions*)	**FY 2001**	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	108.806	121.003	117.398
Current Budget	99.647	142.303	175.646

(U) Change Summary Explanation:

FY 2001	Decrease reflects the SBIR reprogramming and minor program repricing.
FY 2002	Increase due to the following congressional adds: Advanced Photonic Composites and Spectrum Laboratories, Nanotechnology Initiatives, Spin electronics and Ultra Performance Nanotechnolgy Center.
FY 2003	Increase reflects expansion of efforts in the Bio/Info/Micro Sciences project.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
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 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	65.000	90.000	109.336	119.979	134.586	135.310	Continuing	Continuing

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

(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; Nanostructure in Biology and Brain Machine Interface program. 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 BioComputational Systems component will explore, develop, and exploit computing mechanisms in the bio-substrate as well as develop miniaturized hardware to make the concept feasible for a variety of applications of interest to the DoD. The program seeks to achieve both powerful, synthetic computations that can be implemented in bio-substrates, as well as computational models and software tools for prediction and control of cellular internal processes and systems of living cells, extensible to the organism level. First, combining methods for coding information in DNA and related nucleotides, with the massive parallelism capability of nucleotide manipulations, the synthetic computation effort aims to explore and develop powerful and scalable methods for solving highly complex computational problems, and for designing ultra-high density information storage. To make this concept effective, the program seeks to improve time efficiencies and manufacturing capabilities of biological systems production hardware by miniaturizing it to a circuit board size system. Self-assembly of DNA will be exploited to develop programmable

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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

nano-structures and engineered nano-technology for use in layout of molecular electronic devices, reliable crystallography, and for design of novel materials. Second, the program will develop validated computational models of internal cellular processes, capturing complex gene and protein interactions, and simulation tools, for in-silico analysis, capable of predicting cellular spatio-temporal dynamics. The application realm includes characterization, prediction, and control of highly conserved mechanisms of interest to DoD, such as those related to pathogenic processes; mechanisms such as circadian rhythms that underlie war fighter performance and well-being in stressed conditions; and design of bio-sensors. The modeling and simulation capability will be extensible from cell level to higher levels such as organ, organism, and to collective groups of organisms. In addition, the program will begin leveraging the modeling, simulation, and bio-informatics capability to explore new methods of biologically-inspired computing principles, architecture, and design of robust and reliable information processing and networking systems.

(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.

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(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 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, 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 highly adaptive, non-linear robust systems as well as chemical and biological sensors.

(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 (BioMagnetICs) 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

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new opportunities to exploit a wide range of bio-functionality for a number of DoD applications including chemical and biological sensing, diagnostics and therapeutics.

(U) The Brain Machine Interface program will create new technologies for augmenting human performance through the ability to access neural codes in the brain in real time and integrate them into peripheral device or system operations. This will require neuroscience and technology, significant computational efforts, and new material design and implementation. Close-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. In addition, these emerging methods for viewing and measuring processes within the brain will be leverage to determine if it is possible to detect deceptive intent.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- 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 Intra-Cell Evaluation.
  - 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.

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- – 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.
- – 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 single molecular imaging in living cells. Demonstrate imaging of single molecular species in a living bacterial cell.
  - – 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.

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- 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.
- Examine methods of control for directed cell proliferation and cellular stasis at the tissue and organismal level.
- Define parameters for successful application of device for optimizing engineered cells in stasis, differentiation, biopolymers and ablation.
- Examine neural codes for motor and sensor activity.
- Determine open and closed loop controls for using neural signals to control peripheral devices.

• 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 sensitivity magnetic resonance force microscopes.
- Demonstrate a scalable process for producing bio-compatible magnetic nanoparticles (10-100 nm diam.) with stable 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>FY 2003 Plans:</u>**

• BioComputational Systems. ($35.000 Million)
- Implement scalable information processing using DNA coding and manipulations and demonstrate example with a twelve variable graph problem known to be complex as it scales.
- Demonstrate a compact DNA based information storage mechanism with thousands of information objects.
- Exploit self-assembly of DNA structures to achieve arbitrary two-dimensional nano-structures, and explore three-dimensional implementations.
- Implement a first version of the cell models of computation that capture spatio-temporal nature of gene and protein interactions in cells.
- Test and validate the models using first set of data collected from experiments on host-pathogen interactions and molecular level rhythms.

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- Release first integrated version of open source Bio-SPICE (Simulation Program for Intra-Cell Evaluation) for use in biological experimentation.
- Initiate development of Bio-SPICE architecture that enables easy access to public genomic and protein interaction databases, and distributed computing for cell simulation.
- Investigate methods for reduced order cell models and scalability in cell process simulation.
- Demonstrate ability of individual technologies to overcome current problems caused by the inability of numeric algorithmic processes to handle the growing complexity of future C^2 problems.
- Develop capability to utilize complex biological systems for multiple sequential linked events. Assess the possibility of designing a 'digital human' model for a broad spectrum of applications.
- Investigate parallels between biological and non-biological signal processing via advanced modeling and experimentation tools.
- Finalize miniaturized hardware designs for microchemical oligonucleotide manufacture, manipulation, and amplification proof of principle brassboards and initiate development.
- Complete studies on error correction and optimal information encoding of microchemical oligonucleotides.

• Simulation of Bio-Molecular Microsystems (SIMBIOSYS). ($15.000 Million)
  - Engineer living circuits at material interfaces that perform pattern recognition and information processing.
  - Design working devices that incorporate living components as sensors, actuators and computational devices.
  - Explore the utility of using virtual representations of biological systems to specify their engineering properties.
  - Develop scaling laws and phenomenological models for bio-molecular and fluidic transport.
  - Implement models for molecular binding, signal transduction and bio-fluidic transport into microfluidic system software.
  - Investigate methods to extract and integrate several bio-molecular devices on synthetic substrates to form larger scale systems.

• Bio Futures. ($9.130 Million)
  - Develop new engineering tools for designing and enhancing biological regulatory circuits.
  - Develop functional nanofluidic sensors based on cells or cellular components for high sensitivity sensing.
  - Demonstrate nano-scale fluidic systems for the decoupling, quantification and transduction of multi-scale biomolecular signatures.
  - Demonstrate enhancement of natural metabolic capabilities via design-based approaches to genetic engineering.
  - Demonstrate novel nano devices for measuring and regulating cell physiology.

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- Demonstrate biological systems and interfaces, which are self-repairing and retain functional activities over long periods of time.

- Biological Adaptation, Assembly and Manufacture. ($9.500 Million)
  - Transfect and up-regulate genes, or gene products, that produce high-grade tolerance to the stresses of freezing or drying of living cells.
  - Demonstrate application of desiccation tolerance to nucleated and non-nucleated cells.
  - Demonstrate viable integration of genetic strategies for metabolic regulation of living cells.
  - Develop design rules for manufacturing and assembly based on biological principles of development.
  - Develop biofilm utility for DoD needs; including integrated chemical and biological sensing, power generation, antibiotic discovery and concepts of disease transmission.
  - Demonstrate approach of materials manufacturing to organ construction.
  - Demonstrate functional application of desiccated blood components for in vivo application.
  - Develop technologies for making genetic, signal transduction, and metabolic circuits so that organisms (e.g. plants) can be used for detecting chemical and biological materials of interest to DoD (e.g. explosives and chemical and biological warfare agents.)

- Nanostructure in Biology. ($9.370 Million)
  - Demonstrate single electron spin sensitivity for a magnetic resonance force microscope.
  - Determine doping and defect profiles in nanostructures.
  - Perform spin labeled measurements of conformational changes in molecules.Demonstrate the ability to tailor the bio-functionality of nanoparticles to allow attachment (with a high degree of specificity) to a wide variety of cells and bio-molecules including DNA, antibodies, and known pathogens.
  - Demonstrate the ability, using magnetics, to manipulate and control single biomolecules and cells.

- Brain Machine Interface. ($12.000 Million)
  - Initiate extraction of neural and force dynamic codes related to patterns of motor or sensory activity.
  - Determine necessary force and sensory feedback (positional, postural, visual, acoustic, other) from a peripheral device or interface that will provide critical inputs required for closed loop control of a working system or device.
  - Explore new methods, processes, and instrumentation for accessing neural codes non-invasively at appropriate spatiotemporal resolution to provide closed loop control of a peripheral device.

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- Define new materials and device design and fabrication that embody compliance and elastic principles and capture force dynamics that integrate with neural control commands.
- Understand deception behavior of the brain and determine whether this behvior can be detected using non-invasive approaches such as infra-red brain imaging and correlated with remote monitoring techniques.

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

- Not Applicable.

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

- 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 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Information Sciences CCS-02	29.348	12.303	28.000	21.873	19.831	14.844	14.815	Continuing	Continuing

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

(U) This project supports scientific study and experimentation for 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, exploitation of computer capability and development of novel human computer interface technologies.

(U) Computer Exploitation and Human Collaboration will develop information technologies for warfighters to interact with computers in a 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 exchange of information 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. This requires innovation in processing massive amounts of data (e.g., multi-INT) and in parallel processing efficiency. This project will explore new man-machine interaction paradigms, based on implicit interaction where the human's intent and capability is inferred and used to drive the interaction. This will create a more natural interaction and greatly reduce the overhead for the user. (Formerly Ubiquitous Computing and Human Computer Interface)

(U) Bio Futures is the combination of biology with information technologies and physical systems. 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 fields of biological science and technology offer an understanding of systems complexity and robust operation using fundamentally unreliable components, and an understanding that will enable new approaches for information technology, computers and electronics. 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 will develop techniques using information theory for rational medical drug discovery and broad-spectrum antibiotics

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discovery for pathogens confronting the warfighter. Another area of exploration, the Simulation of Bio-Molecular Microsystems (SIMBIOSYS), will develop and demonstrate the capability to simulate and design chip-scale bio-molecular micro-systems with a high degree of multi-disciplinary integration. Both Bio Futures and SIMBIOSYS transferred to the new Bio/Micro/Info Sciences Project (BLS-01) in FY 2002.

(U) The DARPA SPINE (Speech in Noisy Environments) program is creating a automatic speech recognition architecture with prototypes to support broadband and narrowband recognition complicated with tactical military noise such as vehicles, combat noise (weapons), multi-speakers and speech altered by speaker stress. Just as modern computers and calculators can outperform most if not all humans in calculating tasks, SPINE will take advantage of new sensory techniques to potentially outperform humans in the speech recognition domain. If the armed forces are to use automation and robotic technology to extend the force and free soldiers from logistical service support duties, then those information and automation assets must be controlled by natural speech (hands and eyes free) by operators in the field on mission. The technological challenges to such support include adaptation to speaker variation, reverberant noise and speech, operation in negative or low effective signal-to-noise ratios, and overcoming environmental noise variation. To overcome these challenges, the Automatic Speech Recognition (ASR) engine must perform blind source separation, automatic adaptation and learning, and have a greater understanding of noise and the acoustic features of speech. To create such a speech engine to drive our next generation dialog-based interfaces, SPINE must exploit such research topics as: binaural and cochlear hearing techniques, dynamic and graphical modeling, prosody, microphone arrays, advanced language models, and use of non-acoustic communication features.

(U) The Dependable Information Systems component will develop the technology to construct mission-critical military information-systems that will continue to function correctly and provide user services even in the face of component faults, cyber attacks, and attacks initiated by malicious insiders. Special focus of this research is on tactical military systems, embedded systems for communications, surveillance, high-resolution imagery and telescopic, and systems requiring near-real-time response. As these systems become increasingly interconnected in support of network centric warfare, security and fault-tolerance concerns unique to these systems are beginning to emerge. Solutions are being pursued that can work in near real time, dynamically trade performance, functionality and dependability, and heal the system faults and vulnerabilities automatically or semi-automatically with some operator assistance. In parallel, model-based theories of fault diagnosis, decentralized general-purpose algorithms for fault-adaptive distributed systems, fault recovery techniques, simulators for injecting and analyzing fault propagation through the layers of system architecture, and application-oriented experimental platforms are being developed. A theoretical framework will be developed, along with appropriate metrics, to measure the progress in this discipline. Three new initiatives include: Fault Adaptive Systems Technology (FAST), Dependable Architectures, and Self-Regenerative Systems. FAST will address scalable fault management technology that is independent of the application. Dependable Architectures will focus on the dependability of real-time systems and defense against malicious code and insider

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threats. Self-Regenerative Systems will leverage the disciplines of threshold cryptography, software rejuvenation, self-stabilizing systems, and fault tolerance to create dependable systems.

(U) High-Speed Computer Information Systems Bandwidth and Wireless Technology Research focused on improving the end-computer-system bandwidth by an order-of-magnitude to enable true gigabit to terabit information transfer. These efforts ended in FY 2001.

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

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

- Ubiquitous Computing. ($2.684 Million)
  - Developed ad-hoc and indoor location tracking systems.
  - Demonstrated the first version of a small footprint operating system in an operational environment.
  - Developed initial prototype of secure, persistent data storage architecture.
  - Developed specification language and toolkit to program data-flow between heterogeneous devices supporting end-to-end quality of service.
  - Conducted initial data collection and baseline performance measures for current state of the art ASR engines using coded speech in tactical noise.

- Bio Futures. ($24.579 Million)
  - Biological and Amorphous Computing.
    - Demonstrated real-time multi-sensor imaging of cell processes in support of interactive biology.
    - Established focused research initiatives at the interface between biology, engineering and information sciences.
    - Demonstrated use of high resolution imaging technology and signal transduction to affect interactive control over simple biological systems.
    - Conducted investigation of the potential of amorphous computing, a biologically inspired computing paradigm, for development of reliable and robust decision tools and software.

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

- High-Speed Computer Information Systems Bandwidth. ($1.489 Million)
  - Developed 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.
  - Investigated information assurance methods for miniaturized wireless sensor networks.

- Wireless Technology Research. ($0.596 Million)
  - Initiated research on methods that can potentially enable 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.
  - Completed investigation of the information assurance methods for miniaturized wireless sensor networks.

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

- Computer Exploitation and Human Collaboration. ($6.930 Million)
  - Complete development of specification language and toolkit to program data-flow between heterogeneous devices supporting end-to-end quality-of-service.
  - Develop new forms of human-computer interaction that enable human and computers to work as synergistic teams.
  - Investigate efficient processing that increases the speed of parallel processing.
  - Test on challenge datasets for image processing or superpositioning of information.
  - Investigate an adaptive visual display capability to maximize information conveyance.

- Speech in Noisy Environments (SPINE). ($4.750 Million)
  - Establish baseline high noise performance levels.
  - Refine scalable metrics for evaluations in military environments.

- Dependable Information Systems. ($0.623 Million)
  - Evaluate novel credentials-based infrastructure approaches for mitigating insider threats in large enterprise networks.

(U) <u>FY 2003 Plans:</u>

- Speech in Noisy Environments (SPINE). ($9.700 Million)
  - Incorporate core Automatic Speech Recognition (ASR) algorithms into new robust ASR prototype.
  - Define protocols, metrics, and scenarios for SPINE experimental tasks.
  - Establish data-type standards for multi-modal input devices (in support of plug-and-play and system independent design).
  - Baseline ASR components in worst-case noise environments.
  - SPINE-2 evaluation with coded speech in tactical noise.
  - Evaluate first year’s core research for delivery to SPINE team performers.

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- Computer Exploitation and Human Collaboration. ($9.600 Million)
  - Develop efficient processing algorithms that increase the speed of parallel processing by factor of 10 exploiting new mathematical paradigms.
  - Test the algorithms in a warfighter intelligence environment.
  - Demonstrate scaling with computational powers of emerging processing algorithms.
  - Improve devices to perceptually deliver pertinent information to users.

- Dependable Information Systems. ($8.700 Million)
  - Fast Adaptive Systems Technology (FAST)
    - -- Develop application-independent model based algorithms for mission-level fault adaptation, system-level fault diagnosis.
    - -- Develop visualization, fault-injection, and simulation tools for validating fault management approaches.
  - Dependable Architectures.
    - -- Develop novel architectural approaches to detect malicious insider activity including discrimination between normal and anomalous insider behavior (based on a number of parameters such as key strokes, operating system calls, application usage etc); trace ability of system object usage (be able to determine who uses what, when, and how via watermarks, audit trails, event logs etc).
    - -- Develop methodologies for specifying security policies that are context sensitive, comprehensive, and consistent; and enforcement mechanisms that detect policies violation before damage is done by malicious code or malicious insider activity.
    - -- Develop mechanisms for continuous monitoring of user behavior and system actions to defeat malicious insider; develop novel response mechanisms (dynamic privilege modification and access revocation).
    - -- Develop defense mechanisms that exploit the inherent attributes of real-time mission-critical system architectures.
  - Self-Regenerative Systems.
    - -- Leverage the disciplines of threshold cryptography, software rejuvenation, self-stabilizing systems, and fault-tolerance.
    - -- Create a foundation for self-regenerative information systems.
    - -- Develop measures of merit and metrics of various aspects of information system dependability to allow researchers, designers, vendors, users and operators to make quantitative dependability evaluations.

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

- Not Applicable.

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(U) Schedule Profile:

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Electronic Sciences ES-01	22.488	25.943	20.000	19.879	16.873	14.844	14.815	Continuing	Continuing

(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 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. 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. Previously funded by the Director, Defense Research and Engineering but managed by

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DARPA, funding for this effort is now budgeted by DARPA to more closely align the resource authority with the managerial responsibility for the program.

(U) The Macro-Molecular Engineering Program will develop nanoscale engineering for macroscopic functionality incorporating biological warfare sensors, energy engineering and fast photo refractives.

(U) The Photonic Interconnection Fabric Program seeks to generate new communications, dominated signal/image processing architectures and introduce a new paradigm for parallel computing.

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

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

- Terahertz Technology. ($5.627 Million)
  - Demonstrated the best semiconductor quantum-well approaches to sources for the terahertz spectral region.
  - Demonstrated semiconductor quantum-well detectors.
  - Identified system requirements to achieve space communications, upper-atmosphere imagery and close-operations covert communications.

- University Opto-Centers. ($12.826 Million)
  - Demonstrated initial chip-scale integrated photonic, electronic and MEMS modules.
  - Identified the most compelling DoD module applications and measured level of industry commitment to adopt chip-scale integration approach.

- Advanced Photonics Research. ($4.035 Million)
  - Developed photonic composite material modeling, design, growth, analysis, processing and device fabrication.

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

- Terahertz Technology. ($2.192 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. ($11.551 Million)
  - 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.

- Semiconductor Technology Focus Centers. ($6.000 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.

- Advanced Photonics Research. ($4.200 Million)
  - Continue research in photonic composites and device fabrication.

- Spectrum Lab. ($2.000 Million)
  - Initiate technology development.

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(U) **FY 2003 Plans:**

- University Opto-Centers. ($5.707 Million)
  - Design and fabricate prototype modules using the system-on-a-chip approach developed earlier in the program.
  - 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.

- Semiconductor Technology Focus Centers. ($9.000 Million)
  - Develop the interface methodology for efficient handling and compilation of design object information for complex military integrated circuits.
  - Develop circuit architectures that reduce long interconnect.
  - Develop novel device fabrication and integration approaches for deeply scaled transistors and architectures for high performance mixed signal circuits for military needs.

- Macro-Molecular Engineering. ($2.293 Million)
  - Develop BW sensor detectors.
  - Demonstrate photo refractive response time.
  - Demonstrate three-level system energy engineering.

- Photonic Interconnection Fabric. ($3.000 Million)
  - Demonstrate deeper level of photonic integration with CMOS.
  - Use VLSI-Photonic technology to develop system test beds.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

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(U) **Schedule Profile :**

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Materials Sciences MS-01	47.811	39.057	37.646	24.799	19.831	14.844	14.815	Continuing	Continuing

(U) Mission Description:

(U) This project provides the fundamental research that underpins the development of advanced materials for DoD applications. Included in this project is research that exploits advances in nanoscale and biomolecular materials, including computational based material 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).

(U) One of the major thrusts of this project 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) A new initiative in Engineered Bio-Molecular Nano-Devices and Microsystems seeks to engineer assemblies of organic and inorganic molecules showing tremendous promise as the basis for new types of nano-devices that can be assembled to form high performance microsystems. These microsystems will enable important new capabilities such as high sensitivity sensors and transducers for previously inaccessible optical, biological and chemical phenomenon.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Nanoscale/Biomolecular Materials. ($6.574 Million)
  - Demonstrated enhanced performance from materials and processes incorporating nanostructured components.
  - Demonstrated the use of quantum chemistry for the theoretical design of new nanoscale/biomolecular/multifunctional materials and structures.

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- Explored the interface between biological systems and abiotic surfaces and materials.

- Spin-Dependent Materials and Devices. ($12.050 Million)
  - Demonstrated spin-polarized transport across ferromagnetic/semiconductor interfaces.
  - Optimized spin lifetime in semiconductor structures.
  - Demonstrated spin light emitting diode (spin-LED) and spin transistor.

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

- Molecular Electronics. ($8.337 Million)
  - Demonstrated that molecules and/or nanoparticles can self-assemble into functional, regular patterns.
  - Built and tested a 16-bit functional, reversible molecular memory sub-unit.
  - Built and tested room temperature scalable logic gates using molecules.

- Advanced Drag Reduction (Fast Ship). ($6.550 Million)
  - Completed integrated hydrodynamic model development at multiple scales.
  - Completed laboratory-scale calibration and confirmation testing of initial model predictions.
  - Developed model-based performance predictions of different potential drag reduction techniques.
  - Confirmed drag reduction performance predictions from laboratory-scale testing.

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

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

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(U) **FY 2002 Plans:**

- Nanoscale/Biomolecular and Metamaterials. ($6.309 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.
  - Optimize processing schemes for engineering metamaterials with enhanced electromagnetic properties.
  - Model non-linear response of rectifying metamaterials.
  - Investigate and model the physics of nano-scale magnetic materials.
  - Develop approaches for predicting properties and structure of nanoscale and metamaterials using first principle/quantum mechanical models.
  - Explore approaches for integrating biological activities into materials fabrication and engineering.

- Spin-Dependent Materials and Devices. ($14.648 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 an optical quantum bit (qubit) into spin quantum bit.

- Spin Electronics. ($15.000 Million)
  - Continue multidisciplinary efforts to move spin electronics into the nanoscale regime.
  - Couple spin electronics with molecular electronics, nano mechanics and nano photonics.

- Nanotechnology Initiative. ($1.000 Million)
  - Start multidisciplinary in nanotechnology.

- Ultra Performance Nanotechnology Center. ($2.100 Million)
  - Initiate efforts in ultra-performance nanotechnology and identify specific DoD targets.

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(U) **FY 2003 Plans:**

- Nanoscale/Biomolecular and Metamaterials. ($7.646 Million)
  - Produce and evaluate novel and/or cost-efficient materials using biological synthesis approaches.
  - Develop theoretical understanding of three dimensional exchange biased ferromagnetism in nanocomposite magnetic metamaterials.
  - Demonstrate the ability to predict, design and fabricate a metamaterial that exhibits a predetermined microwave response.
  - Develop and demonstrate a theoretical understanding and predictive modeling capabilities for metamaterials that exhibit "left-handed" properties and/or a negative index of refraction.
  - Conduct experiments to validate the first principle/quantum mechanical models for predicting properties and structure of nanoscale and metamaterials.
  - Continue to explore approaches for integrating biological activities into materials fabrication and engineering.

- Spin-Dependent Materials and Devices. ($20.000 Million)
  - Demonstrate a simple high speed, low power opto-electronic circuit using spin coherent devices.
  - Demonstrate electronically excited spin-coherent devices for high-speed digital circuits.
  - Demonstrate a very high-speed circuit using spin dependent transport devices.
  - Demonstrate a scaleable, spin-based implementation for quantum logic gates.

- Engineered Bio-Molecular Nano-Devices and Microsystems. ($10.000 Million)
  - Develop techniques to enable 3D heterogeneous integration and self-assembly methods spanning diverse technologies such as fluidics, MEMS, electronics and photonics.
  - Develop new and innovative technologies in the areas of architecture, design, growth, processing, 3D manipulation, control, interconnection, fabrication and integration of organic and inorganic materials.
  - Develop fabrication techniques that incorporate compact instruction sets for autonomous self-replication.

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(U) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	310.496	358.494	424.940	410.808	399.724	393.906	397.675	Continuing	Continuing
JASON ST-01	2.509	1.500	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Intelligent Systems and Software ST-11	74.838	80.570	95.500	118.704	104.523	108.250	124.791	Continuing	Continuing
High Performance and Global Scale Systems ST-19	126.227	140.599	200.440	151.967	147.600	115.646	107.509	Continuing	Continuing
Information Assurance and Survivability ST-24	70.908	77.738	51.000	65.555	86.183	100.820	105.537	Continuing	Continuing
Asymmetric Threat ST-28	36.014	58.087	78.000	74.582	61.418	69.190	59.838	Continuing	Continuing

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

(U) The Computing Systems and Communications Technology program element is budgeted in the Applied Research Budget Activity because it funds projects directed toward the application of advanced, innovative computing systems and communications technologies.

(U) The JASON project funds an independent group of distinguished scientists and technical researchers that provides analysis of critical national security issues.

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(U) The Intelligent Systems and Software project develops new information processing technology to provide fundamentally new capabilities of critical importance for a wide range of national security needs. This will enable advanced information systems (a) to more effectively accomplish computing and decision-making tasks in stressful, time sensitive situations; (b) to become active, autonomous agents/assistants of the warfighter by collecting, filtering, synthesizing and presenting information in a timely and relevant form; (c) to automatically exploit large volumes of speech and text in multiple languages; and (d) to revolutionize human-computer interaction via using spoken and written English and foreign languages.

(U) The High Performance and Global Scale Systems project develops the computing, networking, and associated software technology base underlying the solutions to computational and information-intensive applications for future defense and federal needs. These technologies will lead to successive generations of more secure, higher performance, and more cost-effective microsystems, associated software technologies, advanced mobile information technology and prototype experimental applications critical to defense operations.

(U) The Information Assurance and Survivability project is developing the technology required to make emerging information system capabilities (such as wireless and mobile systems) inherently secure, and to protect DoD's mission-critical information systems against attack upon or through the supporting infrastructure. These technologies will enable our critical systems to provide continuous correct operation even when they are subject to attack, and will lead to generations of stronger protection, higher performance, and more cost-effective security and survivability solutions scalable to several thousand sites.

(U) The Asymmetric Threat project addresses one of our Nations' most serious threats. They are not threats of a conventional, force-on-force engagement by an opposing military, but threats of an unconventional yet highly lethal attack by a loosely organized group of transnational terrorists or other factions seeking to influence U.S. policy. The goal of this project is to develop technological capabilities and a suite of tools to better detect and prevent attacks upon our critical DoD infrastructures.

(U) Program Change Summary: (*In Millions*)	**FY 2001**	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	330.722	382.294	332.374
Current Budget	310.496	358.494	424.940

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(U) Change Summary Explanation:

FY 2001	Decrease reflects reprogramming of the Software Engineering Technology funding (Project ST-22) to OSD, the SBIR reprogramming and minor program realignments.
FY 2002	Decrease reflects congressional program reductions partially offset by congressional adds for RTAP, Systems Engineering for Miniature Devices, and Secure and Dependable Software.
FY 2003	Increase reflects expansion of Responsive Computing Architecture work in Project ST-19 and Asymmetric Threat programs in Project ST-28.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
JASON ST-01	2.509	1.500	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) This project supports the JASON, an independent group of distinguished scientists and technical researchers that provides analysis of critical national security issues. JASON membership is carefully balanced to provide a wide spectrum of scientific expertise and technical analysis in theoretical and experimental physics, materials, information sciences, biology and other allied disciplines. The JASON process ensures that senior government leaders have the full range of U.S. academic expertise available on issues critical to national security involving classified and unclassified information.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- JASON. ($2.509 Million)
  - Continued studies of interest to DoD in multiple disciplines such as: counter proliferation of chemical and biological weapons; advanced space based systems; advanced computing; multi-layered infrastructure defense; advanced sensor technologies; dispersed land forces technology; battlefield information systems and military communications; ultra low power electronics; and advanced signal processing.

(U) FY 2002 Plans:

- JASON. ($1.500 Million)
  - Continue studies of interest to DoD in multiple disciplines such as: defense against bio-warfare and protection from information attack; operational dominance concepts, including, affordable precision targeting, mobile distributed communications, and future warfare concepts; advanced space based systems; sensor technologies; battlefield information systems; advanced computing; rocket

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and launch technologies; supersonic laminar flow; signal processing; and the intersection of biology, information and physical systems.

(U) **FY 2003 Plans:**

- Not Applicable

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Intelligent Systems and Software ST-11	74.838	80.570	95.500	118.704	104.523	108.250	124.791	Continuing	Continuing

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

(U) This project develops and applies new software database management, and human computer interaction technologies to provide fundamentally new capabilities of critical importance for a wide range of national security needs. This will enable advanced information systems (a) to automatically exploit large volumes of speech and text in multiple languages; (b) to revolutionize human-computer interaction via using spoken and written English and foreign languages; (c) to more effectively accomplish computing and decision-making tasks in stressful, time sensitive situations and; (d) to become active, autonomous agents/assistants of the warfighter by collecting, filtering, synthesizing and presenting information in a timely and relevant form. A major initiative to provide the software necessary for high-end computing needs that are unique to future DoD requirements is also being funded. The project contains two thrusts: Human Language Technology and Software for Situational Analysis. In addition, other stand-alone efforts are being funded: High Confidence Composing Architectures, DARPA Agent Markup Language, Taskable Agent Software Kit, Comparable High Assurance Trusted Systems, Rapid Analytic Wargaming and DefenseNet:

(U) The **Human Language Technology** thrust is comprised of two programs involving human-machine communication -- Communicator and Babylon -- and four efforts involving human-human communication -- Translingual Information Detection, Extraction and Summarization (TIDES), Effective Affordable Reusable Speech-to-Text (EARS), Multispeaker Environments (MUSE), and Global Autonomous Language Exploitations (GALE).

Situation Presentation and Interaction:

- The Communicator program is creating a dialog-based information interface that allows warfighters to acquire theater information, order logistical support, or obtain mission planning execution information without the need for a second human in the information loop. The dialog-based system has a scalable interface that allows the warfighter to accomplish the tasks (e.g. receive orders, reammunition, identify the threat unit to their immediate front) regardless of skill level. The system supports the warfighter without access to a computer screen, keyboard or mouse. In fact, the warfighter does not even need a computer system at all. Early prototypes of the Communicator have impressed Service users. Communicator will specifically deliver a dialog-

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based logistics ordering system for the USMC (logistics management at the tactical level), a maintenance assistant for F-18 ground crews at Patuxent NAS, and a shipboard C2 and status system for the USS SEA SHADOW.

- Babylon provides the tactical warfighter with real-time, face-to-face speech translation during combat and humanitarian operations in foreign territories. The program addresses domain-specific translation accuracy and response time. Rudimentary versions of the program relying on simple dictionaries and phrases have been deployed on a test basis in Afghanistan. Future versions will offer most flexible and fluid translation capability that will be more conducive to normal human speech.

Automated Exploitation of Speech and Text in Multiple Languages:

- Translingual Information Detection, Extraction and Summarization (TIDES) aims to revolutionize the way time-critical intelligence is obtained from speech and text, dramatically increasing the quantity, quality, and timeliness of reporting. TIDES is developing impressive new technology to enable English-speaking operators and analysts to exploit the huge amounts of speech and text that are available electronically but currently unexploitable due to vast volumes or insufficient foreign language skills. This will enable commanders to carry out critical missions and protect U.S. forces around the world. TIDES is creating powerful new capabilities for Detection (finding or discovering needed information), Extraction (pulling out key information), Summarization (substantially shortening what a person must read), and Translation (converting foreign language material to English).

- Effective Affordable Reusable Speech-To-Text (EARS) will create speech-to-text (automatic transcription) technology whose output is substantially richer and much more accurate than currently possible. EARS is a passive listening technology focusing on the most critical languages and media for a wide range of national security applications. It will enable effective automatic detection, extraction, summarization, and translation from broadcasts and telephone conversations. One follow-on program is planned to build on the accomplishments of EARS -- Multiple Speaker Environments (MUSE). MUSE will focus on producing readable transcripts from multi-party speech from command centers and meeting rooms. A second follow-on program -- Global Autonomous Language Exploitation (GALE) will develop techniques for discovering critical intelligence by autonomously exploiting large volumes of streaming speech and text in multiple languages. GALE is intended to exploit the value of information products generated by EARS and TIDES.

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(U) Two complementary efforts are budgeted in the **Software for Situational Analysis** thrust: the Information Management Program and the Rapid Knowledge Formation program.

- The Information Management (IM) program increased the productivity of the Defense analyst by offering high performance retrieval, search and data extraction. The IM program developed algorithms and tools for clustering, classifying, visualizing, navigating and extracting critical data from extreme high volume sources based on an analysis of the meaning of information content of the information sources.

- The Rapid Knowledge Formation (RKF) program objective is to enable subject matter experts who are not Artificial Intelligence (AI) experts to build, share, and reuse large knowledge bases. RKF technologies will be evaluated in challenge problem experiments in microbiology and tactical ground combat. Technology challenges include direct knowledge entry by non-AI experts, coordinating entry of possibly overlapping and inconsistent knowledge by geographically distributed individuals, and achieving a knowledge entry rate (without AI training) of twice that of today's AI expert. The large knowledge bases (10^6 axioms) created by RKF are need for such complex problems as the detection and identification of evasive and concealed targets, offensive and defensive information operations, and Weapons of Mass Destruction (WMD) capability assessments of terrorist organizations. By the end of the RKF program, a number of sets of knowledge engineering and development tools will be provided to DoD and government organizations to be incorporated into their intelligence and warfare analysis systems. In addition, the new High Precision Knowledge Formation (HPKF) initiative will develop tools to build rich, complex, highly specialized knowledge bases needed to support precision tactical operations. Ground warfare tactics exhibit great variety and complexity, and depend greatly on complex relationships between natural and man-made elements of the battlefield. HPKF will develop tools to construct, maintain, and update knowledge about terrain features, mobility factors, sensor characteristics, weapons effects, and engagement tactics in combat situations ranging from desert warfare through infantry operations in jungle to urban combat. It will enable automated forces and planning systems to achieve precision engagement of hostile ground forces, both mechanized and dismounted.

(U) The High Confidence Computing Architectures program will provide a new generation of high-end high confidence computing systems for the national security and industrial user community (2007 – 2010). HCCA will address a number of critical technology barriers over the next decade: (1) extensibility of Moore's Law; (2) software availability/reliability of large scale computing systems; (3) integral hardware, software, application robustness; (4) intrusion resistance; (5) run-time software brittleness; (6) time-to-solution; and (7) cost of developing, operating, and maintaining DoD national security applications. This program, in conjunction with a complimentary high productivity computing system program

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funded under this program element in Project ST-19, will create a new generation of high confidence computing systems characterized by balanced system architecture including high effective bandwidth, robust implementation, and responsive software/hardware components. These new systems will address on-going software challenges that confront both development and use of current high-end systems and applications, such as programming productivity, performance, portability, scalability, reliability, and tamper resistance. This effort has direct and crucial importance to national security and the intelligence communities.

(U) The DARPA Agent Markup Language (DAML) program will develop technologies to enhance interoperability among intelligence and combat information systems. It will extend the framework of the World Wide Web to go beyond documents and include active sensors, software tools, and databases, thus enabling agent-based software to exchange information automatically. DAML will develop a language to characterize software agents in machine-readable semantics (ontology), describing their data needs, data products, and services supplied. DAML will be demonstrated in operational environments, including both intelligence analysis (InteLink) and tactical battle management. The result will be new abilities to integrate, automatically, information across a variety of heterogeneous military sources and systems. In addition, the new DARPA Intelligent Software Toolkit (DIST) initiative will provide a set of tools to transform existing intelligence and command/control software to operate in network-centric computing environments, using DAML ontologies and service descriptions. Without automated tools, the cost of bringing older software systems into network-centric computing environments will be prohibitive. Tools will correlate application-specific ontologies to shared database schema, construct translators from application data structures to database schema, and build mediators that convert product streams from publishers to subscribers. The tools will be prototyped and evaluated within existing C4ISR support systems that contain high data-rate signal processing, sensor exploitation, and engagement planning applications.

(U) The Taskable Agent Software Kit (TASK) program will develop tools for the construction and analysis of multi-agent systems that realize a global objective through local decisions based on embedded models of the mission, the environment, and interaction with other agents. These synthesis and analysis tools will provide a sound, common engineering foundation for the development and deployment of high confidence agent-based computing solutions to a spectrum of military problems requiring robust, scalable, decentralized approaches in dynamically changing environments. While many agent-based systems are currently being built to support militarily relevant applications such as information retrieval and logistics, development methods are ad hoc and little is understood about how to engineer desirable global behaviors from local, autonomous actions and decisions or about how to mitigate and contain potentially undesirable emergent behaviors, particularly in highly dynamic and uncertain environments. This effort will explore methods derived from Control Theory, Decision Theory, and Operations Research for correctly modeling and building agent-based systems. Experiments will reveal the qualitative aspects of environments that favor the use of agent-based systems over conventional, centralized approaches. Beginning in FY 2002, the program will focus on surveillance and targeting missions for cooperative autonomous vehicles.

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(U) The Composable High Assurance Trusted Systems (CHATS) program is developing the tools and technology that enable the core network services to be protected from the introduction and execution of malicious code or other attack techniques and methods. These tools and technologies will provide the security services needed to achieve comprehensive-secure, highly distributed, mission-critical information systems for the DoD. A unique feature of CHATS is that these system capabilities will be developed by engaging the open-source community in security functionality for existing open-source operating systems. Additionally, DARPA will engage the open-source community in a consortium-based approach to create a “neutral”, secure operating system architecture framework. This security architecture framework will then be used to develop techniques for composing OS capabilities to support both servers and clients in the increasing network-centric communications fabric of the DoD. In FY 2003 the CHATS program will move to project ST-24 in this program element.

(U) The goal of the Rapid Analytic Wargaming (RAW) program is to develop a faster than real-time analytical simulation to support U.S. readiness for both symmetric and asymmetric missions in the operational, analytical and training domains. The program will develop technologies to generate a full spectrum of known and emergent behaviors that will expand existing tools developed for more conventional conflict simulation to more realistically portray and project today’s asymmetric threats.

(U) The objective of DefenseNet (DNET) is to dramatically increase the robustness, security and performance of the DoD information infrastructure by exercising architectural options based upon optical network components. The current Internet packet/router “connectionless” network architectures and fragile protocols no longer satisfy minimal DoD requirements either for security (e.g. the lack of attribution) or for performance (Quality of Service, Bandwidth). Recent advances in optical communications components and networks, driven by huge commercial investments in the past few years, have presented the DoD with a unique opportunity to rethink and deploy modern optical-based networks to meet its future mission needs. These new architectures promise inherently secure, symmetric (peer to peer) communications with bandwidths of 1000 times current DoD infrastructures. DefenseNet is budgeted in project ST-28 in FY 2002.

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

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

- Situation Presentation and Interaction. ($14.969 Million)
  - Demonstrated and evaluated dialogue performance for USMC small unit logistics; completed a complex travel task requiring negotiation twice as fast with automated service support as with the best human assistance.

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– Demonstrated and evaluated interaction of tasks with real-time, web-based, public data.
– Demonstrated in-vehicle dialogue for information services and navigation.

- Intelligent Software for Multi-lingual and Coalition Environments. ($21.513 Million)
  – Demonstrated ability to speed up the selection of valuable stories from news broadcasts (9-fold improvement).
  – Created a first generation text and audio processing system for integrating and evaluating additional capabilities.
  – Conducted a successful integrated feasibility experiment in the area of bio-security with Third Fleet personnel.
  – Conducted an initial evaluation of summarization technology.

- DARPA Agent Markup Language (DAML). ($14.496 Million)
  – Completed DAML language specifications.
  – Released working version of Briefing Tool for Intelink.
  – Released working version of DAML Search Tool on Intelink.
  – Released working version of DAML Ontology Creation Tool on Intelink.
  – Defined requirements to DAML for supporting non-pre-planned Agent interoperations.
  – Demonstrated utility of DAML Ontology Creation Tools to enhance the storage, access and organization of archival information at the Center for Army Lessons Learned.
  – Investigated alternative approaches to composable, high assurance, trusted systems based on the Robust Open Source development model.
  – Investigated the feasibility of and alternative approaches to high assurance trusted implementation languages and tools.
  – Investigated alternative approaches to development of both the high assurance trusted system protection profiles and the high assurance languages and tools.

- Taskable Agent Software Kit (TASK). ($4.750 Million)
  – Defined metrics for analysis of agents in the C4I military environment.
  – Performed agent-design method experiments.

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- Reuse Technology Adoption Program (RTAP). ($2.780 Million)
  - Developed an enhanced business model for software development.
  - Explored infrastructure characteristics needed to host a true "Global Information Grid."
  - Experimented on integrating specification-based testing with architecture specifications.

- Software for Situational Analysis. ($16.330 Million)
  - Deployed scalable prototype analysis environment in defense application with the ability to perform analysis across multiple repositories of information (including retrieval based on meaning, indexing, filtering based on relevance to user task, user defined alerting, and categorizing).
  - Demonstrated secure, distributed, repository architecture supporting digital objects of arbitrary type.
  - Developed and conducted user-centered value-added evaluation.
  - Demonstrated direct knowledge entry by a novice (2K axioms/month) for a military problem.

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

- Situation Presentation and Interaction. ($13.719 Million)
  - Communicator.
    - -- Finalize and present to the dialog and speech communities, the evaluation protocols and metrics for heterogeneous human computer dialog systems.
    - -- Transition Small Unit Logistics prototype to USMC for continued refinement and limited production in support of the Small Unit Logistics ACTD and the Commandants Warfighter Laboratory at Marine Corps Base Quantico.
    - -- Define and publish final (release) version of the Galaxy-Communicator 4.0 hub architecture for general use in the dialog systems development community.
    - -- Finish evaluation of commercial "smart-phone" technology vs. military-specific prototypes for cost, ruggedness, and other selection-based criteria.
    - -- Conduct proof of concept demonstration of Communicator technology on the USS SEA SHADOW and with F-18 maintenance crews.
    - -- Evaluate a follow-on research program for dialog systems.

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-- Promote standardization with the Galaxy-Communicator architecture through the World-Wide-Web-Consortium Voice Browser Group (W3C-VB).

– Babylon.

-- Establish baseline hardware design for handheld translation technology.

-- Upgrade DARPA one-way technology to limited two-way translation.

-- Initial software decision approvals for full-featured DARPA two-way translation.

-- Multi-lingual data collection: Pashto, Dari, Farsi, Arabic, Mandarin, and two languages to be determined (for contingency operations).

-- Production of prototype hardware handheld devices for field evaluations and acceptance.

-- Initial coordination with U.S. Army PM Soldier for software integration into land warrior Block III (version 3.0).

• Automated Speech and Text Exploitation in Multiple Languages. ($22.071 Million)

– Translingual Information Detection, Extraction and Summarization (TIDES).

-- Demonstrate ability to detect and track events described in English and Chinese news sources.

-- Create an initial capability to process Arabic text and audio sources.

-- Demonstrate ability to extract key information (about people, places, organizations, and relationships) from English sources.

-- Conduct an initial evaluation of machine translation technology.

– Effective Affordable Reusable Speech-To-Text (EARS).

-- Launch effort to develop automatic techniques to produce rich, readable transcripts of broadcasts and telephone conversations in English, Chinese, and Arabic.

• Software for Situational Analysis. ($12.026 Million)

– Rapid Knowledge Formation.

-- Demonstrate knowledge entry rate of 50K axioms/month from each of 25 subject matter experts in a biowarfare challenge problem.

-- Assess multi-user (25-50 individual) system design.

-- Resolve scaling bottlenecks.

-- Create complex theories using undergraduate biology and medical curricula.

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- High Confidence Computing Architectures. ($4.000 Million)
  – Initiate industry concept studies in high confidence computing and critical technologies required to realize a high productivity computing system to support critical DoD high capability computing missions in the latter part of this decade.
  – Initiate assessment of critical technology barriers, such as system robustness and brittleness, for high-end systems to be implemented in the latter part of this decade.

- Composable High Assurance Trusted Systems (CHATS). ($6.400 Million)
  – Develop an operational prototype of the Composable High Assurance Trusted System.
  – Develop operational capability of candidate high assurance trusted implementation language and tools.
  – Validate the CHATS for resistance to malicious code and other system attack techniques and methods.
  – Investigate the range and alternative high value applications and services needed and required to interoperate with the composable high assurance technology.
  – Develop protection profiles for the preferred applications and services.
  – Investigate alternative approaches to lifecycle management for the high assurance trusted operating systems technology; identify the best alternatives.

- DARPA Agent Markup Language (DAML). ($14.737 Million)
  – Define toolset for C2 application of DAML technologies.
  – Perform experimental analysis of Intelink DAML Briefing Tools.
  – Deploy DAML Search Tool on operational Intelink node.
  – Demonstrate Prototype DAML Ontology Creation Tool for web applications for the Military and National Intelligence Community.
  – Prototype selected DAML tools to enhance search and retrieval tools at the Center for Army Lessons Learned.
  – Conduct experimental analysis of DAML applications for naval and joint C2 interoperability including participation in Millennium Challenge.
  – Create repository of over 1,500,000 DAML statements on World Wide Web for experimental evaluation and design.

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- Taskable Agent Software Kit (TASK). ($5.617 Million)
  - Publish initial design and analysis techniques in two of the original three focus domains: (a) control and analysis of autonomous vehicles in dynamic environments and (b) decentralized, competitive resource allocation for logistics.
  - Perform final empirical validation experiments in competitive resource allocation and initial integration experiments in command and control domain.
  - Define consolidated evaluation scenario and series of challenge problems in surveillance and targeting.

- Reuse Technology Adoption Program (RTAP). ($2.000 Million)
  - Explore peer-to-peer communication models in context of military requirements.
  - Experiment with technologies for developing/evolving coalitions of software components.

(U) **FY 2003 Plans:**

- Situation Presentation and Interaction. ($13.405 Million)
  - Communicator.
    -- Transition Communicator technology to services based on proof of concept results. Communicator follow-on
    -- Publish multi-modal specification of the Galaxy-Communicator architecture.
  - Babylon.
    -- Integrate speech recognition engines into natural language parsers and translators.
    -- Distribute multilingual corpus to R&D community.
    -- Receive feedback from evaluators on DARPA two-way technology (deliver patches and fixes); units remain in operational use.
    -- Deliver upgraded handhelds (capable of supporting two-way technology) to software developers.
    -- Delivery of "alpha" versions of DARPA two-way software for initial user testing.
    -- Final languages selected for development.
    -- Language digital resource repository populated at Defense Language Institute (DLI).

- Automated Speech and Text Exploitation in Multiple Languages. ($22.095 Million)
  - Translingual Information Detection, Extraction and Summarization (TIDES).

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-- Define architecture for a unified text and audio processing system that integrates Translingual Information Detection, Extraction and Summarization technologies.
-- Demonstrate ability to extract key information from Chinese or Arabic sources.
-- Demonstrate initial machine translation capability from Chinese to English.
-- Demonstrate ability to port capabilities to another language within three months.
-- Improve the performance of the enriched automatic speech transcription algorithm.

– Effective Affordable Reusable Speech-To-Text (EARS).
-- Create, demonstrate, and evaluate prototype system for producing rich transcripts from broadcasts in English, Chinese, and Arabic.

– Multispeaker Environments (MUSE) and Global Autonomous Language Exploitation (GALE).
-- Launch effort to develop automatic techniques to produce rich, readable transcripts of multiparty speech from command centers and meeting rooms.
-- Initiate multifaceted effort to develop techniques for discovering critical intelligence autonomously, exploiting huge volumes of streaming speech and text in multiple languages.

• Software for Situational Analysis. ($ 12.750 Million)

– Rapid Knowledge Formation.
-- Demonstrate building and use of an integrated knowledge base of 1 million axioms in less than one year.
-- Conduct Biowarfare challenge problem and develop proof-of-concept knowledge base in coordination with end users for transition purposes.

– High Precision Knowledge Formation (HPKF).
-- Evaluate ability of 1 mega-axiom knowledge base to support high-fidelity problem solving methods for situation awareness and tactical command and control.

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-- Define tactical air/ground combat challenge problem, select external decision aids, and prototype export/import of knowledge with those aids.

- High Confidence Computing Architectures. ($11.990 Million)
  - Perform industry concept and critical technology review for target high confidence system in the (2007 – 2009) time frame.
  - Perform university-oriented critical technology assessment and concept evaluation for target systems in the (2007 – 2009) time frame.
  - Release alpha system level confidence metrics and benchmarks to guide future program research and development activities.
  - Initiate multi-year research activities in high confidence computing systems.

- DARPA Agent Markup Language (DAML). ($11.510 Million) Deploy DAML-based technology to other intelligence service providers.
  - Prototype suite of DAML tools to enhance the storage, access and organization of archival information at the Center for Army Lessons Learned.
  - Deploy DAML tools as infrastructural support for naval and joint C2 interoperability.
  - Prototype DAML tools as infrastructural support to enhance the use of agents for coalition warfare command and control.

- DARPA Intelligent Software Toolkit (DIST). ($7.750 Million)
  - Prototype suite of additional tools to encapsulate legacy software to support DAML ontologies, logics, and service descriptions.
  - Build example mediators to convert data among DAML ontologies, referencing external knowledge bases as necessary.

- Taskable Agent Software Kit (TASK). ($9.000 Million)
  - Deploy initial agent-creation tools with predictable behaviors based on mathematical techniques for modeling and analyzing agent behavior.
  - Evaluate agent design techniques on initial challenge problems in surveillance.
  - Implement a framework for composing multiplayer games include those that are static, dynamic, and repeated games with uncertainty.

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- Rapid Analytic Wargaming. ($4.000 Million)
  - Establish operational testbeds in conjunction with one or more transition partners (Joint Forces Command (JFCOM), Joint Staff, and others).
  - Derive scalable abstract behavioral framework baseline to facilitate the identification and reuse of key military concepts across a broad context and multiple force structures and missions.
  - Develop hybrid gaming technologies that rapidly generate known and emergent behaviors and decisions for asymmetric scenarios based on historical and current context.
  - Test initial gaming technologies against both existing analytical tools and recent-world scenarios.

- DefenseNet. ($3.000 Million)
  - Identify and select initial prototype network, infrastructure exercising architectural options, test QoS and performance
  - Expand testbed activities to test scaling of DNET bandwidth to endpoint devices of single streams in the range of 10-40Gb/sec.
  - Examine the options for tethering of DoD wireless communications networks from the DNET backbone.

(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 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
High Performance and Global Scale Systems ST-19	126.227	140.599	200.440	151.967	147.600	115.646	107.509	Continuing	Continuing

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

(U) This project develops the computing, networking, and associated software technology base underlying the solutions to computational and information-intensive applications for future defense and federal needs. These technologies will lead to successive generations of more secure, higher performance, and more cost-effective microsystems, associated software technologies, advanced mobile information technology and prototype experimental applications critical to defense operations. The project is comprised of four primary components in FY 2003 - - Networking, Responsive Computing Architectures, Network Embedded Technology, Autonomous Systems Control and Augmented Cognition - - plus two stand alone efforts: the Mixed Initiative Control of Automa-Teams and the Intelligent Micro-Systems Technology program.

(U) The **Networking** component is developing new paradigms in networking technologies to meet the future defense and national security needs. The aim is to create highly robust and rapidly configurable networking capabilities essential for both secure national infrastructure and ad-hoc military networks through key innovations in software and hardware technologies. The results will be applicable to wired, wireless and mixed networks. The Networking component is comprised of Network Modeling and Simulation, Active Networks, Ultra High-Performance Networking, and Coordinated Large Scale Network.

- The Network Modeling and Simulations (NMS) program (formerly Active Management and Control) will develop tools to address the challenge of predicting the end-to-end and internal behavior of complex networks over a broad range of time scales, network sizes and composition. New models and simulators will enable reliable and rapid planning, design, analysis and configuration of military and emergency networks with minimal manual intervention.

- The Active Networks program (formerly Active Management and Control) investigates the use of smart packet processing to enable new strategies in rapid network service introduction and enhancement. Active network-based authentication mechanisms will enable highly dynamic access control not possible with today's IP infrastructure.

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- The Ultra High-Performance Networking Program is advancing transparent all-optical networking and gigabit wireless techniques to dramatically enhance bandwidths available to end-applications. Gigabit end-speeds are essential for a multitude of defense applications involving distributed processing of sensor outputs. All-optical self-healing architectures are also being developed as a part of a concerted effort to create high-confidence networking infrastructure. New paradigms in wireless link techniques are also being explored to make possible robust networking in complex, harsh environments.

- The Coordinated Large Scale network (CLSN) program seeks to develop technology that will support a 1,000,000 node coordinated network that will function in real-time. This technology will enable self-adjusting networks for such application as high resolution, high fidelity reconnaissance and surveillance with a resolution of 12mm.

(U) The **Responsive Computing Architectures** component is bringing needed flexibility to DoD systems. It is developing integrated computing subsystems that will respond in real-time to dramatic changes in mission application requirements and operating constraints based on the mission-of-the-day. The current projects are focused on energy/power management, quality of service, and algorithm/application computing diversity and scalable computing efficiency. This technology has direct and significant impact for military systems such as the Land Warrior/Objective Force, ground and airborne autonomous devices, distributed sensors, space sensors, and intelligence collection ground systems. The Responsive Computing Architecture component is comprised of Power Aware Computing and Communications, High Productivity Computing Systems, Thermodynamics of Randomized Computing, Network-Centric Infrastructure for Command, Control and Intelligence, Adaptive Computing Systems, and Quorum.

- The Power Aware Computing and Communications (PAC/C) program is developing an integrated software/hardware power management technology suite comprised of novel techniques that may be applied at all levels of a system from the chip to the system level. Embedded military computing systems such as future Land Warrior systems, autonomous devices, distributed sensors, and space sensors have extreme dynamic computational and energy requirements. PAC/C will enable embedded computing systems to reduce energy requirements by ten to one hundred-fold for energy constrained military applications ranging from hand-held computing devices to unmanned aerial vehicles.

- The High Productivity Computing Systems (HPCS) program will provide the DoD with significant technology and capability advancements for the national security and industrial user communities by filling a high-end computing gap between today’s late 1980’s based technology High Performance Computing (HPCs) systems and the promise of quantum computing. This program is targeting high-

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end computing, medium to long term, national security missions where U.S. superiority and security is threatened, according to two recent DoD studies. The proposed technology development plan is part of a three-phase program, in conjunction with the high confidence research component (Project ST-11) that will extend up to the end of this decade. The three phases are concept study, research and development (R&D), and full-scale development. Early identification of high-end computing application computing requirements, metrics, and performance prediction tools will be used through out the program to assess both technical and schedule progress. As an example, performance (efficiency) for critical national security applications will be improved by a factor of 10X to 40X.

- The Thermodynamics of Randomized Computing program is a revolutionary approach to energy reduction based on the fact that randomized algorithms, because of their associated error probability, allow computing with greater uncertainty or (thermodynamic entropy than corresponding deterministic algorithms) and hence consume less energy. This program will provide an early proof-of-concept of the proposed novel idea from an energy perspective.

- The Network-Centric Infrastructure for Command, Control and Intelligence (NICCI) program is developing technologies to automatically create virtual work centers, called "habitats," that can bring together the right combination of people, computer systems, robots, and data to accomplish a specific set of tasks. These habitats can be dynamically reconfigured because they are "aware" of the interrelated combat conditions and the context of the environment. New technologies will be developed to allow the warfighter, at any level of command, to rapidly assemble a habitat that addresses the needs of a specific task e.g., geographic situation awareness, or command interfacing with coalitions.

- The Adaptive Computing Systems (ACS) program allowed DoD to develop a wide variety of specialized systems by reusing a relatively small set of hardware designs, each of which can be affordably produced in high volumes. Much of the technology developed under ACS was transitioned to the application focused Mission Specific Processing (MSP) program funded under PE 0602702E, Project TT-06, Advanced Tactical Technology.

- The Quorum program (formerly Systems Environments) developed, reusable software capabilities and tools that can be customized easily by programmers to meet the demanding scalability and dependability requirements of network-centric combat systems, such as shipboard computing environments, avionics mission computing systems, and anti-aircraft defense. Quorum technologies are the foundation for two key open architecture initiatives: (1) Aegis Baseline 7 Phase II, the new open architecture for the Aegis Weapons System and (2) extension of Boeing’s Bold Stroke avionics architecture for the F-15 to allow cross-platform coordination across tactical networks in support of time-critical retargeting. In both cases, Quorum's quality-of-service middleware and resource management technologies allow satisfaction of mission-critical requirements on an evolving commercial off-the-shelf technology base, reducing development and life-cycle costs. In addition, Quorum has allowed DoD system integrators to keep short life span computation systems (2-5 year lifespan) current and effective in platforms with far longer service lives (20 plus years).

(U) The **Network Embedded Technology** component will develop software technology to build distributed, real-time, and embedded applications, ranging from tens of computing nodes to over a million. Each program is driven by carefully selected Open Experimental Platforms (OEPs) to facilitate the continuous evaluation of progress and end-user influence. By using major theoretical breakthroughs during the past decade in hybrid systems, statistical physics, finite-size scaling, generative programming, and distributed control, the programs have solid foundation to achieve the ultimate goal of revolutionizing how software-intensive embedded platforms are built for the DoD. The Network Embedded Technology component is comprised of Networked Embedded Systems Technology and Program Composition for Embedded Systems.

- The Networked Embedded Systems Technology (NEST) program will provide robust coordination and synthesis services subject to extreme timing, power, and resource constraints for networked embedded systems. With the coming wave of MEMS-based fine-grain distributed control applications, "smart" structures for active acoustic and structural damping and large space-antennas built with Gossamer structures impose great technical challenges. These applications contain at least 100,000 simple computing nodes. NEST is about unprecedented scaling. If successful, the reusable code-base, tools and reference applications delivered by the program, will dramatically simplify the software development task in a wide range of future weapon systems. If not done, application developers will need to constantly reinvent theoretically involved and computationally complex solutions for embedded subsystem coordination and synthesis, which cannot provide sufficient guarantees for predictable behavior of large-scale systems.

- The Programmable Composition of Embedded Software (PCES) program is developing technology to support faster, more reliable development of software for distributed embedded software for intelligent systems. This technology will enable programmers to safely and productively integrate so-called "cross-cutting" aspects, such as concurrency, synchronization, security, and memory management, along with the core functionality that implements intelligent software interaction with a diverse suite of sensors and actuators in real-time. If successful, the reusable code-base, tools and reference applications delivered by PCES will leverage human effort to rapidly produce higher-quality, more adaptable software. It will also assure that the resulting software achieves required properties and will enable the production of high-confidence military systems that fundamentally depend on software operation.

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(U) The **Autonomous Systems Control** component will develop the tools necessary to deploy, control and coordinate the full spectrum of autonomous system resources effectively and efficiently in order to ensure mission success. DoD systems are rapidly becoming hybrids, incorporating both humans and autonomous system components such as robots and software agents; how the software will achieve that integration is the subject of this component. The Autonomous Systems Control component is comprised of Autonomous Negotiation Teams and Autonomous Software for Learning Perception & Control.

- The Autonomous Negotiation Teams (ANTS) program (formerly Mobile Code Software) will develop the software technology to resolve time-critical constraints in logistics and mission planning. The resource management problem will be solved via the interaction of lightweight, mobile software components using a bottom-up organization approach and negotiation as techniques for resolving ambiguities and conflicts. The technology will enable designers to build systems that operate effectively in highly decentralized environments, making maximum use of local information, providing solutions that are both good enough, and soon enough.

- The Autonomous Software for Learning Perception & Control program will program autonomous mobile robots to independently perform a variety of military tasks in a diverse spectrum of complex, dynamic environments. The goal is to achieve validated performance at near-human levels in a full range of real-world environments for perception-based autonomous vehicle driving/navigation and effective interaction of robots with humans. This program is pursuing several alternative approaches to augment pre-programmed activities and responses with powerful learning-derived competencies for perception and control analogous to those of biological systems. In other words, this software will enable autonomous systems to modify their behavior in response to real-world situations or barriers. Integrated perception, including fusion of data from multiple sensor and multiple processing modalities of the same data will reduce operator intervention and achieve semi-autonomous operation. The result will be highly capable robots that can learn new tasks and adapt quickly to new environments with minimal programming effort, with numerous applications in the battle space of the future.

(U) The **Augmented Cognition** component focuses on developing technologies to augment the warfighter's cognitive capacity and capabilities. This new area for expanding human capability seeks to augment human cognition and performance in the way that weapons, vehicles and sensors extend human abilities. The hypothesis of this emerging field is the impressive progress in neural science, computation and miniaturization can now be leveraged to enable new concepts of warfare. The Augmental Cognition component contains two efforts: Augmented Cognition and the Perceptual Processing Display program.

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- The Augmented Cognition (AugCog) program will develop the means to measure a subject's cognitive state in real time and manipulate it to accomplish the functions. The goal of the Augmented Cognition program is to develop methods that integrate digital devices that support memory, perception, and thinking, and link that support with the user's context state information to directly improve the overall cognitive performance of the warfighter.

- The Perceptual Processing Display program focuses on exploiting neuroscience and perceptual processing technologies to redesign devices that deliver information to the human perceptual system. These new devices will be able to extract relevant signal from extraneous background noise, through perceptual modeling. This program will develop technologies that simplify relevant, and eliminate irrelevant, information to improve perception, comprehension, memory, inference, and decision-making. Specifically, this program will demonstrate the manipulation of perceptual data along hundreds of dimensions of the human perceptual system, and will result in the doubling of human information processing performance.

(U) The Mixed Initiative Control of Automa-teams (MICA) program is developing algorithms, software, modeling and simulation capabilities to perform multi-level planning, assessment and control of distributed, autonomous combat forces. MICA will provide a strike commander the operational and mission planning tools to select optimal team composition, to perform dynamic tasking and re-tasking of teams, and to generate cooperative routes for autonomous Unmanned Combat Air Vehicles (UCAVs) in stressful operational missions, especially suppression of enemy air defenses. Mixed initiative control will develop collaborative strategies and tactics for these teams under the supervision of a single human operator, with adjustable autonomy determining the degree of human authority desired or required during task execution. Through the exploitation of control science metrics for stability, performance and robustness, these teams of cooperative, autonomous vehicles such as UCAVs will accommodate uncertainty in both the operating environment and feedback information, as well as address the presence of an intelligent adversary and fixed/mobile threats in the battlespace. An open experimental platform will be employed to evaluate these hierarchical battle management and control methodologies with humans-in-the-loop, initially in a simulation and subsequently in a hardware demonstration.

(U) The Intelligent Micro-Systems Technology (IMST) program will develop highly adaptable, highly integrated components (micro-systems) with the ability to self-assess and adapt in real-time, optimize their micro-level performance, and provide new levels of macro-level functionalities to meet the needs of new generations of military sensor and weapon systems. This program adds and integrates intelligence from the antenna, RF signal conditioning, signal processing, and sensor fusion at four levels of abstraction: hardware, component, system, and applications. The

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distribution of intelligence at multiple levels will enable revolutionary applications thus far impossible due to the inflexible, centralized control architectures in previous generations of DoD systems.

(U) The Data Intensive Systems (DIS) component developed innovative data access techniques to enable new military capabilities with high rate sensor data streams and irregular data base memory access requirements. DIS developed hardware, software, and algorithmic approaches to computer memory organization and access to eliminate severe bottlenecks in present designs for defense applications such as dynamic, sensor-based processing, battlefield data-processing integration, and high-speed cryptographic analysis.

(U) The Information Technology Expeditions program developed technologies for software-programmable adaptive computing systems.

(U) The Systems Engineering for Miniature Devices (SEMD) research project focuses on the integration of existing/emerging technologies in the areas of mobility, power, sensing, actuation, communication, and computation, with a special focus on the software issues involved in controlling and programming these devices.

(U) The Secure and Dependable Software Program will develop technologies to enable production of secure and dependable software for military's mission-critical applications.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Networking. ($24.053 Million)
  - Investigated alternative approaches to large-scale network engineering including simulation technology.
  - Demonstrated performance improvements of 100 percent for large multicast sessions based on active suppression of redundant acknowledgement and retransmission messages.
  - Integrated active network capabilities into Run-Time Infrastructure (RTI) for use with high-level architecture (HLA)-compliant simulations; held joint demonstration with Defense Modeling and Simulation Office (DMSO).
  - Developed models of traffic, network, and control suitable for on-line parameter tuning, dynamic reconfiguration, fault detection, and for meeting DoD mission critical requirements.

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- Initiated validation of modeling and simulation tools, and demonstrated predictive power of the models using measured network data.
- Initiated collaborative modeling and simulation experiments with Navy and Air force labs.
- Implemented and demonstrated non-specific congestion manager that coordinates and ensures fair throughput for multiple applications.
- Developed radar image enhancement algorithms using coherent processing of signals from multiple radar sources connected by a very high-speed network.
- Developed survivable key management and distribution architectures to protect against compromise and enable rapid network recovery and reconstitution.

- Data Intensive Systems and Software. ($11.589 Million)
  - Demonstrated advanced cache-based approaches for data-intensive applications.
  - Demonstrated compilation for new hierarchical memory architecture including automatic selection of instruction placement in either CPU or processors in memory.
  - Demonstrated the impact of in situ processing and a high-level graphics language abstraction that enables the computation 1,000,000 ray-patch intersections per second.
  - Demonstrated the processor-in-memory (PIM) concepts necessary to improve the execution of the NAS Conjugate Gradient benchmark by 20-fold over today's state-of-the-art memory limited applications.

- Adaptive Computing Systems (ACS). ($18.095 Million)
  - Implemented final Adaptive Computing Systems (ACS) design tool suites using high-level entry, e.g., for Java, C, Matlab, and Khoros.
  - Demonstrated 100x – 1000x reduction in compilation time for ACS implementations.
  - Implemented and demonstrated C compiler for hybrid chips.
  - Implemented and demonstrated ACS/heterogeneous processing Matlab design environment.
  - Implemented and demonstrated selected benchmark algorithms using ACS automated development environmental/tool aided design.
  - Demonstrated ACS defense system insertion for high dimensionality sonar beamforming, synthetic aperture radar (SAR), signal processing, and automatic target recognition (ATR).
  - Defined high level and low-level optimization approaches to implement Application Specific Integrated Circuit (ASICs).

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- Defined the appropriate levels of customization that provide the greatest performance benefit for Digital Signal Processor (DSP) intensive ASIC based systems such as wide band adaptive radar receivers and IR image processing.
- Began the design of custom cell libraries and module generators.

• Quorum Program. ($28.966 Million)
- Released prototype distributed object software with real-time Quality of Service (QoS) management.
- Demonstrated support for mixed workloads of hard, soft, and non-real-time applications.
- Demonstrated QoS-driven fault detection and recovery within 500 milliseconds.
- Developed intermediate representations and mechanisms for code composition and transformation.
- Developed models, specifications, code interpretations, and implementation mechanisms for embedded systems aspects, such as timing and fault tolerance.
- Developed common graph-based program representations for software analysis.
- Developed initial reusable embedded system aspect software.

• Power Aware Computing. ($20.040 Million)
- Demonstrated flight-capable Synthetic Aperture Radar (SAR)/Automatic Target Recognition (ATR) system recognizing 30 target types in presence of camouflage concealment deception.
- Continued evaluation of candidate power aware technologies and techniques that have high payoff potential for planned subscale demonstrations.
- Identified potential small and medium scale power aware subscale demonstration candidates: Land Warrior system, smart munitions, autonomous, unmanned combat air vehicles, distributed sensors, and space sensors.
- Defined a series of real world power aware system level energy scenarios for planned subscale platforms and applications.
- Defined and initiated development of a power aware framework tool suite that will permit multiple level heterogeneous power aware systems to be integrated to enable system level power aware trades.

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- Mobile Code Software. ($17.429 Million)
  - Demonstrated and evaluated software agent's ability to approximate behavior tradeoffs and to utilize negotiation in advanced logistics scenario with a 3-second response requirement.
  - Demonstrated and evaluated software agent's ability for bottom-up organization in advanced logistics scenario with 100-1,000 components.
  - Prototyped implementation of negotiation technology in real-time scenario with a 500-millisecond response requirement.
  - Developed methods for maintaining and updating critical information (system and resource states, global time, etc.) system-wide, without centralized depository.
  - Investigated event/time triggered system synthesis methods subject to time, functional, performance, safety and security constraints.
  - Investigated design methods of embedded generators that guarantee selected behaviors of the generated systems.

- Information Technology Expeditions. ($2.605 Million)
  - Demonstrated adaptive reprogramming of hardware within a single clock cycle.
  - Defined operating systems for deeply networked multiple intelligent devices with varying data rates and processing power.

- Next Generation High End Computers Required for National Security. ($3.450 Million)
  - Developed massively parallel processor (MPP) computers that minimize porting effort from current vector platforms.
  - Demonstrated use of MPP architecture for interactive National Security applications.

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

- Networking. ($35.001 Million)

  - Active Networks.
    - - Develop Active Networking techniques for Distributed Simulation Internet Management, including techniques for the channelization of information and for enhanced filtering of data, resulting in the minimization of network bandwidth utilization and end-system receive-processing requirements in distributed simulations.

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- - Develop active Enabled Intrusion Detection and Response (IDR) prototype demonstrating more flexible, adaptive, autonomous, and dynamic Intrusion Detection with detection, tracing, response, and repair functions and including integration techniques such as capability encapsulation, self-adaptation, and intruder wrapping.
- - Develop and demonstrate obfuscation techniques for mobile agents that may be executing on malicious hosts, including self-monitoring and recovery techniques for obfuscated mobile agents.
- - Develop an active network operating system (AN OS) focused on a policy-free security architecture and availability within an active network, including inter-process (e.g., applet, servelet, execution environment) isolation within the same virtual machine.
- - Explore active network technology within mobile computing environment, including active power management, data prioritization, ad-hoc network hopping, and active security.
- - Develop active network techniques for distributed network management, resource control, and distributed network service deployment, configuration, and management.

– Network Modeling and Simulation.
- -Initiate the development of models to predict internal and end-to-end behavior of large networks at multiple time scales and resolutions.
- - Implement models and validate them in an experimental DoD test bed network with distributed simulation capability.
- - Investigate alternative control mechanisms to achieve desired service level agreements and Quality-of-Service.
- - Develop models for anomaly detection, fault diagnosis, and prediction of congestion onset and dynamics in large networks.
- - Develop a fast, programmable emulation capability that can facilitate on-line tests of control to assess unintended consequences.

– Ultra High-Performance Networking.
- - Design secure communication interfaces for gigabit-end flows.
- - Develop and demonstrate optical access nodes based on fast tunable-channel transmitters.
- - Demonstrate correlation of multi-gigabit per second transfer of radar signal streams from multiple sources.
- - Prototype digital amphitheater application tying thousands of event participants via an integrated video portal.
- - Demonstrate telepresence application with dramatically reduced processing overhead.
- - Demonstrate multiple video blanket media streams and client side browsers for display of these streams.

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- Responsive Computing Architectures. ($25.155 Million)
  - Power Aware Computing and Communications.
    - - Demonstrate 10X power/energy aware reduction techniques incorporating compiler, algorithms, runtime systems, and mission optimization approaches.
    - - Demonstrate 10X power/energy aware reduction techniques incorporating micro-architecture, input/output, memory, and component optimization approaches.
    - - Conduct preliminary PAC/C energy simulation/modeling framework concept demonstration.
    - - Select small and medium scale prototype candidates.
    - - Define small and medium scale prototype demonstration definition.
    - - Select final small and medium subscale platforms and application demonstrations.
  - High Productivity Computing Architecture.
    - - Identify application requirements.
    - - Initiate productivity benchmarks and stressmarks.
    - - Develop innovative programming models and virtual machine forms.
    - - Explore scalable computing programming and profiling techniques.
  - Network-Centric Infrastructure for Command, Control and Intelligence.
    - - Develop Joint Service experimental plans.
    - - Conduct studies and develop prototypes to assess the ability of emerging COTS infrastructure technologies to support habitat construction, evolution, and interaction.

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- Network Embedded Technology. ($27.000 Million)

  – Network Embedded Systems Technology.
  - - Conduct experimental and theoretical investigations on *phase-transition* effects, i.e., the dramatic changes from being easy to becoming intractable, in problems that involve the simultaneous satisfaction of multiple constraints.
  - - Investigate methods for the prediction of characteristics and for the detection of proximity of phase transitions.
  - - Develop experimental prototypes to test and evaluate algorithms and programs that solve constraint satisfaction problems by leveraging knowledge of phase transitions.
  - - Develop scalable, lightweight *coordination-services*, e.g., synchronizing clocks globally, achieving global consensus on shared data etc., for network embedded software technology applications.
  - - Investigate deterministic and probabilistic methods for self-stabilizing protocols.
  - - Investigate design approaches for the customization of coordination-services to specific applications.
  - - Develop formal modeling and verification techniques for coordination-services.
  - - Develop formal modeling methods for integrated coordination service packages.
  - - Investigate methods for the aggregation and automatic composition of coordination services to form one integrated package.
  - - Develop low-cost, open-experimental platforms for network embedded software technology.
  - - Demonstrate scalability and fault resilience of basic coordination service components in simple network embedded software technology applications.

  – Program Composition for Embedded Software.
  - - Develop techniques for incremental formal analysis and transformation of networked embedded software.
  - - Develop language representation and compiler techniques for aspect-oriented programming of fine-grained and coarse-grained aspect-oriented programming of embedded systems.
  - - Develop model-driven tools and representations for generating, optimizing, and configuring component-oriented middleware for networked embedded systems.
  - - Develop quality-of-service (QoS)-enabled services for persistence, fault tolerance, and multi-media sensor/intel data transmission.
  - - Demonstrate pair-wise interacting aspects and transformation strategies for coordinated operations between manned/unmanned air vehicles and shipboard command and control centers.

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- Autonomous Systems Control. ($26.864 Million)

  – Autonomous Negotiation Teams.
    - - Demonstrate ability to identify autonomous negotiating teams needed for cooperative flight scheduling and maintenance planning.
    - - Prototype implementation and evaluation of negotiation in real-time mission planning for UCAV operations.
    - - Demonstrate ability for hierarchical coalition formation in real-time.
    - - Demonstrate negotiation protocols for large, hierarchically organized coalitions.
    - - Integrate utility for the selection of negotiation strategies to meet goals of convergence, optimality, and timeliness.
    - - Demonstrate stable goal tracking ability under changing environments.
    - - Demonstrate avoidance of conflict by changing plans.
    - - Demonstrate ability to negotiate tasks in common real-time multiple target tracking problem with requirements of 0.25 ft error, 90% probability of disambiguation, and 500-millisecond response time.

  – Autonomous Software for Learning Perception & Control.
    - - Demonstrate behavior scalability and reuse.
    - - Demonstrate learning compatible knowledge representations.
    - - Demonstrate task-based, sensor data exploitation.
    - - Identify metrics for evaluation and associated evaluation methodologies.

- Augmented Cognition. ($11.200 Million)
  – Develop robust, non-invasive, real-time, cognitive state detection technology for measuring the cognitive processing state of the user.
  – Determine if a spatially-distributed, multi-modal, context-specific display system, as opposed to a conventional single screen display, provides an environment that makes it easier for people to encode, store, and retrieve information.
  – Evaluate/develop advanced cognitive function measuring devices, and establish principles and guidelines for their use.
  – Develop a set of conversational interruption strategies with cues that help bring a user back into the context of the interrupted task at the point where the user was interrupted.
  – Establish cognitive relaxed computer dialog architecture to support the warfighter interaction with the computer.

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- Mixed Initiative Control of Automa-Teams (MICA). ($11.779 Million)
  - Develop theories and baseline algorithms to assign autonomous combat vehicles to task-oriented teams.
  - Develop theories and baseline algorithms to assign mission-derived subtasks to each combat vehicle in a team.
  - Develop theories and baseline algorithms to generate routes and event schedules for each combat vehicle in a team.
  - Build an initial open experimental simulation environment, driven by UCAV suppression of mobile air defense elements.
  - Deploy a second phase open experimental simulation environment incorporating multiple UCAV teams and multiple command levels.

- System Engineering for Mini Devices. ($2.600 Million)
  - Continue system engineering for mini devices effort.

- Secure and Dependable Software. ($1.000 Million)
  - Initiate secure and dependable software development effort.

(U) **FY 2003 Plans:**

- Networking. ($29.150 Million)
  - Active Networks.
    - - Explore use of active network technologies in multiple environments, including high performance clusters and grids, advanced hardware platforms, and deeply networked systems.
    - - Investigate specification, formal analysis and verification of active network languages and methodologies.

  - Network Modeling and Simulation.
    - - Implement a measurement-driven, model-based, hybrid simulation emulation tool in a multi-operator network, achieving high level architecture compliance.
    - - Demonstrate 100x scalability in network size and 10 to 50x speed in simulation over existing techniques, and demonstrate network behavior prediction at scales ranging from msecs to hours over a wired network, and a wireless network of 100s of nodes.
    - - Demonstrate on line network controls including Quality-of-Service provisioning, dynamic reconfiguration, and on-line fielding of situation specific protocols.

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- - Demonstrate 10 to 100x improvement in fault diagnosis time, over current techniques.
- - Develop reduced order and aggregate models of network suitable for faster prediction and control.

– Ultra High-Performance Networking.
- - 10-node synchronization and peer discovery experiment.
- - Measurement and modeling of urban indoor and outdoor network links.
- - Design precision (1cm) network based geo-location system scalable to 100 nodes in an indoor setting.
- - Design base architecture for high-confidence networks that are robust to single-point physical-layer failures.
- - Demonstrate 10 node synchronization and peer discovery using impulse network nodes.
- - Demonstrate synchronizing activation and deactivation of an edge network composed of 100 nodes, scalable to 10,000 nodes.
- - Demonstrate hybrid optical / RF self-healing link at 600 Mbps.
- - Design a large-scale ad-hoc network including peer-to-peer with security mechanism that do not rely on hierarchical keys.
- - Demonstrate support to dynamic coalitions of components.

– Coordinated Large Scale network (CLSN).
- - Develop computation and coordination network technology that exploits MEMs technology application.
- - Initiate development of scale-down 1,000 node CLSN.
- - Use 1,000 node CLSN to demonstrate that the stringent computational requirements imposed by fine-grained distributed structure, extreme scaling, environment-induced high failure rates, and complex decentralized control can be met.

• Responsive Computing Architectures. ($59.140 Million)

– Power Aware Computing and Communications.
- - Incorporate experimental data collected at each of the five power aware levels: 1) mission, 2) subsystem/algorithm, 3) software/compilation, 4) operating systems, 5) architecture/devices into the power aware simulator library.
- - Provide a Beta release of the PAC/C energy aware simulator and modeling framework for the PAC/C subscale developers to evaluate.

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- - Develop firm power aware objectives for each of the major subscale application demonstrations based on experimental data and power aware simulation tools.
- - Finalize selection of the power aware technologies to be incorporated and demonstrated for each of the planned power aware subscale demonstration projects which include the following application areas: distributed sensors, space processing, Land Warrior/Objective Force, and communications.
- - Continue the development of the final subscale demonstration projects and provide interim demonstrations.

– High Productivity Computing Architecture.
- - Perform an industry concept and critical technology assessment review for viable HPCS systems for potential implementation in the (2007 - 2009) timeframe.
- - Perform university oriented critical technology assessment and concept evaluation for viable HPCS systems for implementation in the (2007 - 2009) time frame.
- - Release alpha “value-based” productivity metrics and benchmarks to guide future program research and development activities.
- - Define, approve and implement a multi-year research plan in high productivity computing systems.
- - Explore effective high bandwidth hierarchical memory subsystem for scalable high-end computing systems.
- - Explore a system architecture that will adapt to dynamic application types and work loads.
- - Address large system brittleness by exploring hardware and software reliability/fault tolerance capabilities, active application software bug tolerance, and intrusion identification and resistance.
- - Explore balanced “productive” system architectures balancing processors, memory, interconnects, software, and programming environments.

– Thermodynamics of Randomized Computing.
- - Establish the feasibility of using randomized algorithms to save energy via entropy management.
- - Define the computing model (BTFM) and demonstrate the thermodynamic behavior of randomized algorithms.

– Network-Centric Infrastructure for Command, Control and Intelligence.
- - Establish integration test bed.
- - Demonstrate decentralized mechanisms for enforcement of rules about habitat membership and task sequencing in habitats.

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- Network Embedded Technology. ($36.500 Million)

  – Networked Embedded Systems Technology.
  - - Develop embeddable services for transition-aware constraint solvers.
  - - Demonstrate real-time synthesis using transition-aware constraint solvers.
  - - Develop experimental prototype for distributed, anytime constraint solvers.
  - - Develop customizable and adaptable solutions for coordination-services for network embedded software technology applications.
  - - Extend self-stabilization approaches to hybrid systems.
  - - Develop formal models and formal verification of coordination service components.
  - - Develop tools for the automatic composition and verification of application specific coordination service packages.
  - - Demonstrate the synthesis of an optimized coordination service package on the experimental platform such as distributed avionics or space-based phased array antenna.
  - - Demonstrate the application design process and evaluate performance up to a 10^3 node system.

  – Program Composition for Embedded Software.
  - - Develop analysis techniques for multi-aspect interference.
  - - Develop control services for multi-media sensor data.
  - - Develop binding-time analysis and optimization tools.
  - - Develop dependence-based aspect composition techniques.
  - - Develop techniques for ensuring real-time and fault-tolerance service in combat systems.
  - - Demonstrate program composition services on shipboard weapons resource scheduling system.

- Autonomous Systems Control. ($25.500 Million)

  – Autonomous Negotiation Teams.
  - - Demonstrate ability of autonomous negotiation targets (ANTs) to resolve conflict under time limit by re-negotiating plans or modifying goals.

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- - Demonstrate ability of ANTs to maintain stability in changing environment.
- - Conduct final demonstration: coordinated, superior response in real-time ECM simulation.
- - Demonstrate ability to dynamic re-synthesis of the application under time limit using distributed constraint solvers.

– Autonomous Software for Learning Perception & Control.
- - Demonstrate adaptive generation of complex behaviors.
- - Demonstrate multi-sensor phenomenology enabled, outdoor navigation.
- - Demonstrate methods for directing perceptual attention.
- - Interim evaluation of human-humanoid interaction.
- - Demonstrate a trainable, perception-based, autonomous (indoor) navigation capability.
- - Develop integrated command control and resource management tools for large-scale distributed system of unmanned systems.
- - Demonstrate distributed autonomous behaviors that aggressively exploit the sharing of information between multiple unmanned surface vessels (USVs) to achieve cooperative target tracking, interception, and self-defense.

• Augmented Cognition. ($21.900 Million)

– Augmented Cognition.
- - Investigate how to develop and utilize necessary technologies such that routine tasks can be delegated to the computer as much as possible, thus freeing humans to attend to tasks that truly need their attention.
- - Identify the underlying neural generators and the respective neural mechanism of cognitive state. The functional formulation of neuronal mechanisms will allow predictions under a variation of parameters, such as stress and attention.
- - Conduct performance evaluations to baseline capabilities useful for controlling and monitoring human and robot systems, and demonstrate significant gains in effectiveness when cognition extends memory and perception, and focus of attention.

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- - Demonstrate and evaluate methods to use multi-modal query of digital memory to augment cognition by rapidly re-setting stylized context.
- - Continue the development of the Functional Optical Imaging sensor system based on Near InfraRed (fNIR) and to validate it as a means to monitor prefrontal cortex activity during select tasks relevant to cognition.
- - Develop a toolkit that allows on-line analysis of a user's self-regulatory mechanisms including sensory response, attentional augmentation of sensation, context updating, performance context tracking, and response and error monitoring.
- - Apply cognitive relaxed computer dialog architecture to support a practical low-cost prototype to demonstrate feasibility of the architecture and components.

– Perceptual Processing Displays.
- - Conduct experiments to determine optimal methodologies and technologies to expand and exploit the perceptual-cognitive processing bandwidth.
- - Develop software and hardware based on human behavior models and neuroscience to detect relevant signal from background noise that results in the extraction of salient information autonomously.
- - Design visual displays that deliver optimal information based on the human visual perception systems.
- - Develop an extremely feature-rich audio-interface based human auditory perception systems.
- - Demonstrate auto-adapting displays that adapt to the person, task, or display device.

- Mixed Initiative Control of Automa-Teams (MICA). ($22.000 Million)
  - Extend algorithms and software to assign autonomous combat vehicles to task-oriented teams.
  - Construct algorithms and software to allocate individual combat vehicles to each collaborative subtask.
  - Design algorithms and software for collective trajectory generation with collision avoidance and self-reorganization in the presence fixed/mobile threats.
  - Define algorithms and software supporting dialog between human commanders/operators and semi-autonomous entities to communicate recommended courses of action, appropriate feedback information, and decision tuning parameters.
  - Deploy a third phase open experimental simulation platform stressing multi-team coordination, cooperative planning of sensor and weapon platforms, against difficult ground targets, with responsive operator control and intervention.

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- Demonstrate cooperative management of 2-5 teams of 5-10 platforms and one operator with team self-organization in the presence of active threats.
- Build a capstone simulation of an operational challenge problem with 5-10 teams of 20-30 platforms and an active/intelligent adversary.

• Intelligent Micro-Systems Technology. ($6.250 Million)
- Define the characteristics and information technology requirements for intelligent micro-systems at the hardware, component, system, and application levels.
- Devise mathematical models of intelligent Microsystems and validate these models for a range of representative new and planned DoD systems.
- Develop early system concepts and architectural alternatives for selected applications.

(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 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Information Assurance and Survivability ST-24	70.908	77.738	51.000	65.555	86.183	100.820	105.537	Continuing	Continuing

(U) Mission Description:

(U) This project is developing the technology required to make emerging information system capabilities (such as wireless and mobile code/mobile systems) inherently secure, and to protect DoD's mission-critical systems against attack upon or through the supporting information infrastructure. These technologies will enable our critical systems to provide continuous correct operation even when they are subject to attack, and will lead to generations of stronger protection, higher performance, and more cost-effective security and survivability solutions scalable to several thousand sites. Technologies developed under this project will be exploited in High Performance and Global Scale Systems (Project ST-19), Command and Control Information Systems (Project CCC-01, PE 0603760E), Information Integration Systems (Project CCC-02, PE 0603760E), and in other programs to satisfy defense requirements for secure and survivable systems.

(U) Information Assurance and Survivability technologies will be developed for secure communications and computing for correlating and fusing cyber sensors and to mitigate national and defense computing infrastructure vulnerabilities that could be exploited by an information warfare enemy. Information Assurance and Survivability focuses on early prototypes of software technologies leading to protection for large-scale, heterogeneous networks and systems usable over a wide range of performance in diverse threat environments.

(U) The Dynamic Coalitions program will develop technologies to support the secure creation of dynamic coalitions including the necessary technologies for policy management, group communications, supporting security infrastructure services, data sharing, and joint collaboration spaces. These areas are critical for future warfighting scenarios as outlined by Joint Vision 2020, which states that future military operations will be increasingly conducted jointly, both with multiple branches of the U.S. Armed Forces and with allied, and coalition forces, requiring increased levels of interoperability.

(U) The Fault Tolerant Networks (FTN) program will develop technologies to provide continuous and correct network operation even when attacks are successful. These technologies will reduce the amount of damage sustained during an attack, allowing networks to maintain an acceptable, minimum level of functionality. Technologies for strengthening networks will be developed by introducing fault tolerance capabilities against possible attacks at the network level, emphasizing integrity and availability; and technologies for mitigating potential vulnerabilities

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associated with denial of service attacks. The Critical Infrastructure Protection (CIP) program, as part of the FTN program, will transition networking technology to critical information and telecommunication systems that are essential for minimum network operations.

(U) Intrusion assessment technologies will be developed to detect security threats through correlation and analysis of observed/reported activities. Assurance and dynamic integration tools will allow security and survivability to be inserted into legacy systems, and will enable critical systems to reconfigure and survive in the face of detected threat and successful attack. Autonomic architectures will be investigated to provide intelligent but reflexive defenses that adapt rapidly in milliseconds to block or withstand many classes of known and unknown attacks. These technologies will assure code integrity, contain malicious code, and tolerate remaining attacks using survivable architectures. Cyber defense increasingly requires a system to monitor its health and to effectively integrate and orchestrate information assurance and survivability technologies. In this pursuit, a display and control architecture that allows warfighters to observe the performance, health and threat state of mission critical information systems and adjust security and survivability attributes is being developed in Cyber Panel technology projects. Cyber Panel will create technologies that enable human-directed command and control over cyber resources, providing operationally relevant cyber situational understanding, mission impact assessment, and cyber course of action planning, analysis, and execution. The Partners in Experimentation program will conduct security technology experimentation with operational military and coalition partners. Operational experimentation will provide valuable feedback to the security technology research and development process as well as demonstrating to operational personnel the benefits of advanced technology. The Partners in Experimentation program transitions to Command, Control and Communications Systems, PE 0603760E, Project CCC-01 in FY 2003.

(U) The Fundamentals of Computer Network Defense (FCND) program will develop the basic theoretical underpinning for securing networked systems. This includes assessing the spread and detection of malicious mobile code, development and validation of security metrics, development of a modeling and simulation environment to assess direct and collateral effects of network attacks, and an understanding of the threats posed by sophisticated adversaries.

(U) The Composable High Assurance Trusted Systems (CHATS) program is developing the tools and technology that enable the core network services to be protected from the introduction and execution of malicious code or other attack techniques and methods. These tools and technologies will provide the high assurance, trusted operating systems (OS) context/basis to host the planned security services needed to achieve comprehensive-secure, highly distributed, mission-critical information systems for the DoD. This project will fundamentally change the existing approach to development and acquisition of high assurance trusted operating systems technology. These trusted operating system capabilities will be developed by engaging the open-source community in security functionality for existing open-source operating systems. Additionally, DARPA will engage the

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open-source community in a consortium-based approach to create a "neutral", secure operating system architecture framework. This security architecture framework will then be used to develop techniques for composing operating system capabilities to support both servers and clients in the increasing network-centric communications fabric of the DoD. These technologies are critical for defensive information warfare capabilities and are needed to ensure that DoD systems of the future are protected from imminent attack. This program was originally funded in this PE under Project ST-11 in FY 2002 and prior.

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

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

- Autonomic Information Assurance. ($14.870 Million)
  - Developed autonomic response architecture.
  - Identified promising assessment methodologies for more effective evaluation of very large information infrastructures.
  - Developed scalable models of very large information infrastructure.
  - Completed an internal study producing a framework for a survivable exemplar Global Information Grid (GIG) system (such as the Global Command and Control System - Maritime (GCCS-M), an operational mission critical information system used by the Navy), and a survivable Cyber Panel.
  - Transferred promising technologies for use by the Fault Tolerant Networking (FTN), Cyber Panel, and OASIS programs in FY 2002 and completed closeout of remaining Autonomic Information Assurance technologies.

- Cyber Command and Control/Strategic Intrusion Assessment. ($23.795 Million)
  - Merged elements of Cyber Command and Control and Strategic Intrusion Assessment to eliminate gap between cyber attack detection at network services level and assessment at system functional level and focused technologies toward a coherent cyber attack monitoring and response management system.
  - Developed correlation and analysis algorithms to detect and track complex multi-phase or large-scale cyber attacks.

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- Developed techniques for assessing cyber attack impact at the system functional level from network-level alerts such as signature, anomaly, and effects-based attack event detections.
- Developed algorithms for evaluating and executing coordinated defensive actions and attack responses, automatic and human-initiated, across a large distributed system.
- Transferred promising technologies for use by the Cyber Panel and OASIS programs in FY 2002 and completed closeout of remaining Cyber Command and Control/Strategic Intrusion Assessment technologies.

• Intrusion Tolerant Systems. ($2.186 Million)
- Transferred promising technologies for use by the Organically Assured and Survivable Information Systems (OASIS) and Cyber Panel programs in FY 2002.
- Investigated market-based and value-based resource allocation mechanisms.

• Fault Tolerant Networks. ($22.403 Million)
- Developed techniques to isolate corrupted or malicious network entities.
- Investigated progress-based network resource allocation mechanisms to prevent denial-of-service.
- Investigated trust-chain techniques for network resource allocation and protection against denial-of-service.
- Designed active techniques for traceback and automated responses.
- Transitioned Secure Border Gateway Protocol (SBGP) to commercial off-the-shelf (COTS) router vendors and established necessary Public Key Infrastructure (PKI) that provides basic authentication and authorization for potential users.
- Developed secure enhancements to the Domain Name System (DNS), which include the operational use of keys, the incremental deployment of secure protocols, and coping with the existence of faulty or malicious secured DNS zones. In addition, research addressed the improvement of the robustness of the DNS, using an arbitrary mesh of trust.

• Dynamic Coalitions. ($7.654 Million)
- Prototyped protocols for negotiation of policies across coalition members.
- Created methods for fast sender authentication, scalable key distribution for creation and rekeying of coalitions.
- Extended existing PKI capabilities with protocols for cross certification of coalition members.

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

- Fault Tolerant Networks. ($35.624 Million)
  - Demonstrate Source Path Isolation Engine (SPIE) experimentation using Collaborative Advance Interagency Research Network (CAIRN) and COTS Intrusion Detection System to show the trace of an attack back to its ingress point soon after attack.
  - Develop capability to provide detection of denial of service attacks on the Quality of Service (QoS) data flow and to isolate the attacking packet streams using the concept of congestion pricing in resource reservation, the security of resource reservation will be enhanced against insider router attacks.
  - Demonstrate a scalable architecture and localized optimization algorithms for constructing a dynamic, topologically sensitive root context for any network topology, thus, removing the dependence of a single, fixed root content for the domain name server (DNS).
  - Develop a system of deployed passive probes and intelligent security gateways to aggregate attack statistics and determine countermeasures for response to attacks on routing protocols.
  - Explore traffic modeling techniques for countermeasures for traffic analysis and denial of service attacks in wired and wireless networks, including the development of a tool set that provides survivable real-time communication services.
  - Design new, efficient algorithms for detecting attacks and faults in optical networks, including models and algorithms for cost-based approach to reserving routes and bandwidth in anticipation of attacks and faults.
  - Develop algorithms for path classification and selection of protocols for creation of resilient network overlays within a modular routing architecture.
  - Revise Internet protocol (IP) and Secure IP (IPSEC) specifications to enhance resilience to traffic analysis.
  - Evaluate onion routing system virtual overlay network for resilience to traffic analysis in operational field use.
  - Evaluate several authenticated resource usage control schemes for preventing distributed service denial.
  - Develop novel implementation of Internet protocol (IP) reducing local service denial risk.
  - Demonstrate algorithms and techniques for providing controlled sharing of medium access, providing traffic cover and patterns.

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- Dynamic Coalitions. ($11.103 Million)
  - Develop extensions to team-based access controls addressing dynamic coalition membership and coalition missions, access to coalition resources at the task level, and modeling the use of self-limiting resource permissions that evolve with the state of mission-oriented tasks.
  - Develop algorithms which will remove dynamic group management bottlenecks by replacement of public-key techniques with much faster secret-key techniques, insertion of computational shortcuts, and potentially, the replacement of cryptography with secret-sharing techniques (for additional performance gains).
  - Develop and demonstrate several intra-domain group key management approaches for mobile subscribers, built around a decentralized, hierarchical architecture: one approach based on current Internet Engineering Task Force (IETF) IPSec multicast key management proposal; a second using same approach modulated by a hysteresis interval for environments with unreliable connectivity; third, an approach using explicit handoff of security associations among key distributors; and finally, an approach using periodic re-keying.
  - Develop general framework for hierarchical access control, decoupling rights authorization from information and service access, resulting in enhanced coalition scalability.
  - Design, develop and integrate new certificate cache architecture with secure group communication system.

- Fundamentals of Computer Network Defense (FCND). ($6.434 Million)
  - Initiate the theoretical limits to securing networked systems.
  - Develop and evaluate metrics for information assurance.
  - Assess the rate of speed of malicious mobile code.
  - Initiate development of modeling and simulation for networks under attack.
  - Explore capabilities of sophisticated adversaries and impact to defense.

- Cyber Panel. ($13.230 Million)
  - Develop information correlation and analysis algorithms to detect and assess widespread attacks.
  - Prototype detectors that can describe and exchange new attack patterns.
  - Demonstrate attack projection and real-time analysis of collective response tactics.

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- Identify and assess new information types that can be used to augment current operating system audit and network packet data sources to allow more comprehensive detection of cyber attacks.
- Investigate methods for allocating, dynamically deploying, and protecting intrusion detection sensors in large networks.
- Combine selected Cyber Panel technologies to demonstrate an initial integrated cyber attack detection, correlation, and response capability.

• Partners in Experimentation. ($11.347 Million)
  - Convert intrusion assessment algorithms into data reduction tools for military computer intrusion detection analysts.
  - Demonstrate situational awareness and interactive "big-board" control of broadly distributed security technologies, including scalable host based defenses, in military operational environment.
  - Transition to PE 0603760E, Project CCC-01, Command, Control and Communications Systems.

(U) <u>FY 2003 Plans:</u>

• Fault Tolerant Networks. ($16.500 Million)
  - Develop a distributed, scalable, reliable, and cost-effective architecture for an active network router that schedules node resources and dynamically reconfigures itself in response to failures.
  - Develop protocols to use fault tolerant consensus to ensure that all correct nodes are making consistent decisions and nodes can immediately route around failures.
  - Design and develop modifications to Source-initiated Ad-hoc Routing Algorithm (SARA) to incorporate techniques for intrusion-resistant mechanisms for Flow-based Route Access Control, multi-path routing, and flow monitoring algorithms.
  - Develop revocation notification for active faulty code and diverse and compensatory authentication techniques for just-in-time authentication capabilities in active networks.
  - Demonstrate reduction in covert channels and traffic analysis vulnerabilities.
  - Develop methodologies for specifying security policies that are context sensitive, comprehensive, and consistent; and enforcement mechanisms that detect policy violation before damage is done by malicious code or malicious insider activity.

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- Determine the unique vulnerabilities and potential avenues of attack on embedded real-time mission-critical systems as they are employed in network-centric warfare and characterize the potential adverse effects on correctness and timeliness of results.
- Develop information systems that can adapt their security posture to changing threat conditions and adjust performance and functionality to maintain an optimum balance among the three system attributes.
- Develop mobile distributed firewall architectures to allow rapid deployment of mobile networks with full enclave protection.
- Investigate mechanisms for digital watermarking of mobile wireless communications to ensure device authentication and protect against terminal compromise.
- Provide public key infrastructure support for rapid revocation of individuals, to include terminal exclusion and network reconfiguration.

• Dynamic Coalitions. ($11.500 Million)
- Develop cryptographic hardware accelerator to speed up cryptographic computations for devices used in coalition networks.
- Demonstrate integrated facilities for transitive delegation, with support for capacity sandboxing, reverse sandboxing, and object caching.
- Develop and demonstrate intra-domain group key management protocols extended to handle mobile key distributors within mobile networks.
- Design and develop a modular architecture and robust key agreement within a dynamic coalition, including reconfigurability and evaluation.

• Fundamentals of Computer Network Defense (FCND). ($6.000 Million)
- Continue study of theoretical limits to securing networked systems.
- Initiate development of the visualization tools needed for a cyber command post.
- Begin command and control concept of operations for network defense.
- Explore very high speed Type 1 and Type 2 encryption for Internet protocol (IP) based networks.
- Explore vulnerabilities of heterogeneous network environments and potential defenses.

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- Cyber Panel. ($6.500 Million)
  - Refine and complete cyber panel components to be transitioned into follow-on system prototype.
  - Develop ability to determine and execute at millisecond speeds effective automatic reactions to cut off local network intrusions.

- Composable High Assurance Trusted Systems (CHATS). ($10.500 Million)
  - Implement prototype adaptations of the preferred applications and services as indicated by the protection profiles.
  - Implement the composable high assurance trusted system and the adapted applications and services on candidate representative DoD mission critical system server fabric.
  - Investigate alternative approaches for extending the composable high assurance technology to the network client fabric.
  - Develop protection profiles for the best candidate high assurance client side trusted systems.
  - Implement the best of the lifecycle support alternatives.
  - Investigate the alternative technology transfer options that provide the best long term persistence and continuity for the CHATS technology and tools.

(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 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Asymmetric Threat ST-28	36.014	58.087	78.000	74.582	61.418	69.190	59.838	Continuing	Continuing

(U) Mission Description:

(U) The most serious threats to our national security, today, are *asymmetric* in nature. They are not threats of a conventional, force-on-force engagement by an opposing military, but threats of an unconventional yet highly lethal attack by a loosely organized group of transnational terrorists or other factions seeking to influence U.S. policy. This new threat brings new technological challenges. Instead of being satisfied with the capability to detect a nation-state as they prepare and execute a conventional military operation, the U.S. will need to develop a capability to detect a small, loosely organized group as they plan and execute an unconventional attack. This new threat will have a smaller mass, exhibit fewer observables, and yet will be more lethal in consequence. Sparse activity that was once too insignificant to notice will need to be detected, correlated, and understood. This can only be achieved by developing a new level of automation to detect, correlate, and understand all of the observable evidence exhibited by these sparse events. Specific needs include: the capability to automatically recognize and identify humans at a distance, to detect any enemy agent performing surveillance of a U.S. target; to automatically discover, extract, and link together sparse evidence of a group's intentions and activities from vast amounts of classified and unclassified information sources; to more precisely model the beliefs and organizational behavior of these small groups to better simulate and wargame our new opponents in this asymmetric world; and to provide more effective collaborative reasoning and decision aids to improve the speed and effectiveness of distributed teams of analysts and decision-makers in these dynamic situations.

(U) The goal of this project is to develop technological capabilities and a suite of tools to better detect and prevent attacks upon our critical DoD infrastructures. Ongoing programs in this project are Human Identification at Distance (Human ID), Evidence Extraction and Link Discovery (EELD), Wargaming the Asymmetric Environment (WAE), Bio-Surveillance, Endstate and DefenseNet (DNET). In addition, two new initiatives: Mis-Information Detection and Generation (MIDGET) and Genisys will be funded in FY 2003. In FY 2003 the DefenseNet and Endstate programs have respectively moved to Projects ST-11 (PE0602301E) and CCC-01 (PE0603760E).

(U) The Human Identification at a Distance (HumanID) program objective is to develop automated multi-modal biometric technologies. These technologies will be used to detect, recognize and identify humans at a distance. Automated biometric recognition technologies will provide critical early warning support against terrorist, criminal, and other human-based threats. Obtaining this information can prevent or decrease the success rate of such attacks and provide more secure force protection of DoD operational facilities and installations. HumanID seeks to develop a

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variety of individual biometric identification technologies capable of identifying humans at great distances in DoD operational environments and for homeland defense. Once these individual technologies are developed, HumanID will develop methods for fusing these technologies into advanced human identification system. This system will be capable of multi-modal fusion using different biometric techniques with a focus on body parts identification, face identification, and human kinematics. Biometric signatures will be acquired from various collection sensors including video, infrared and multi-spectral sensors. These sensors will be networked to allow for complete coverage of large facilities. The goal of this program is to identify humans as unique individuals (not necessarily by name) at a distance, at any time day of night, during all weather conditions, with non-cooperative subjects, possibly disguised and alone or in groups. These technologies will be tested and integrated into the Total Information Awareness (TIA) System funded in PE 0603760E, Project CCC-01.

(U) The objective of the Evidence Extraction and Link Discovery (EELD) program is to develop a suite of technologies that will automatically extract evidence from vast amounts of unstructured textual data (such as intelligence messages or news reports) leading to the discovery of additional relevant relationships and patterns of activity that correspond to unusual events, potential threats or planned attacks. These technologies would be employed to provide more accurate advance warnings of potential terrorist activities by known or more important, unknown individuals or groups. They will allow for the identification of connected items of information from multiple sources and databases whose significance is not apparent until the connections are made. Recent advances in language understanding software will be exploited to provide a capability to automatically extract facts from textual messages, web pages, and other unstructured data sources at a performance level (90% accuracy) comparable to today's ability to extract entities (e.g., people, places, organizations). Search, reasoning, and classification techniques will be developed to enable discovery of relevant information and evaluate it to detect likely threats. Pattern learning algorithms will be extended and scaled to enable learning and evaluation of patterns comprised of relationships among people, organizations, activities, and scenarios, with the ability to distinguish accurately between real activities of interest and explainable unusual events. These technologies will be tested and integrated into the Total Information Awareness (TIA) System.

(U) The Wargaming the Asymmetric Environment (WAE) program's mission is to develop and demonstrate threat specific tools to enable analysts and decision makers to better anticipate, predict, and intervene against terrorists and others who threaten U.S. and Allied interests with asymmetric and asynchronous capabilities. The technical challenges include 1) developing predictive methodologies and technologies that work within the complex and non-linear characteristics of today's asymmetric adversaries, 2) developing predictive technologies that will generalize from individuals to groups, from attack behavior to more subtle enabling behaviors/decisions that precede an attack, and 3) developing emulation (predictive sequences) technologies to allow analysts to test a projected adversary's actions and reactions to potential intervention strategies. WAE's approach to these technical challenges is to exploit a combination of behavioral prediction and computer-based reasoning techniques to automatically identify and model factors reflecting a specific groups "intent" and "points of influence" to support prediction and reasoning – at

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operationally relevant levels - about the future behavior of individuals and groups. This approach goes beyond today's analytical methods to analyze behaviors in the broader context of their political, psychological, and cultural environment. These predictive technologies will be tested and integrated into the Total Information Awareness (TIA) System.

(U) The objective of the Bio-Surveillance program is to develop the necessary information technologies and resulting prototype system capable of detecting a covert release of a biological pathogen by monitoring non-traditional data sources such as animal sentinels, human behavioral indicators, and non-diagnostic medical center. Technical challenges include correlating/integrating information derived from heterogeneous data sources, development of autonomous signal detection algorithms, creation of disease models for autonomous detection, and maintaining privacy protection while correlating heterogeneous data and sources. The program will develop disease models, identify abnormal health detectors, and mine existing human, agriculture, and animal health databases to determine the most viable indicators for abnormal health conditions. The program will perform analyses on hypothesized events to determine which indicators are most valuable to detect bio-terrorist releases. Adjustable privacy protection that could be placed in a medical data system and ensure the anonymity of individual records accessed by the data monitoring software will be developed and tested. A prototype bio-surveillance system will be constructed for a citywide area such as Norfolk, VA and demonstrated in a series of field experiments by injecting simulated biological event data into the real-time data streams of the testbed system. The Bio-Surveillance program will dramatically increase DoD's ability to detect a clandestine biological warfare attack, involving both natural and unnatural pathogens, in time to respond and avoid potentially thousands of casualties.

(U) The Endstate (Effects-based, Nonlinear Analysis and State Estimation) program will explore technology to dramatically improve the DoD's capability to perform vulnerability analyses of networks. Infrastructure networks such as air defense, logistics, electrical power, and petroleum are becoming increasingly coupled. Currently, the DoD has the capability to perform sophisticated analyses of networks separately using high fidelity simulations. Endstate's objective is to develop technology to combine complicated and detailed models of individual infrastructure networks into coherent, accurate, and computationally tractable interdependency models. Such models would support analyses concerning vulnerabilities, alternative courses of action, and consequences.

(U) The objective of DefenseNet (DNET) is to dramatically increase the robustness, security and performance of the DoD information infrastructure by exercising architectural options based upon optical network components. The current Internet packet/router "connectionless" network architectures and fragile protocols no longer satisfy minimal DoD requirements either for security (e.g. the lack of attribution) or for performance (Quality of Service, Bandwidth). Recent advances in optical communications components and networks, driven by huge commercial investments in the past few years, have presented the DoD with a unique opportunity to rethink and deploy modern optical-based networks to meet

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its future mission needs. These new architectures promise inherently secure, symmetric (peer to peer) communications with bandwidths of 1000 times current DoD infrastructures.

(U) The Genisys program will produce technology for an ultra-large all-source information repository to help prevent terrorist attacks on the citizens, institutions, and property of the United States and its allies. To predict, track, and thwart, or at least mitigate attacks, the U.S. needs a full-coverage database including information about all potential terrorists and possible supporters, terrorist material, training/preparation/rehearsal activities, potential targets, specific plans, and the status of our defenses. Current database technology is clearly insufficient to address the need to integrate all relevant existing databases and semi-structured information sources, to automatically populate the new repository with many different and non-traditional data feeds, and to enable the easy creation of new information systems which today exist only in manual form. Today's database technology was defined in the 1980s, but processors, disks, and networks are now a thousand times more capable--Genisys will reinvent this technology to meet today's needs and capabilities. The goal of the program is not only to demonstrate technologies, but also to develop a series of increasingly powerful leave-behind prototypes so that the intelligence community can get value immediately and provide feedback to focus research. These technologies and components will feed into the Total Information Awareness (TIA) System.

(U) The objective of the Mis-Information Detection and Generation (MIDGET) program is to reduce DoD vulnerability to open source information operations by developing the ability to detect intentional mis-information and to detect inconsistencies in open source data with regard to known facts and adversaries goals. A secondary output of the program could be evaluation techniques for use in planning information operations.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Human Identification at a Distance. ($11.807 Million)
  - Developed a fixed site, pilot force protection system to identify humans at a distance in an outdoor operational setting at a DoD facility.
  - Used Specific Service sites as prototype models in designing demonstrations and experiments.
  - Developed and acquired advanced sensors to support the development of eight biometric component technologies.
  - Developed initial algorithms and performed evaluations of biometric component technologies.
  - Performed preliminary assessment of current and future technologies to meet the proposed system needs.

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- Evidence Extraction and Link Discovery. ($17.344 Million)
  - Identified candidate unclassified and classified document collections from which asymmetric threats can be detected.
  - Initiated collection of document collections to use as basis for technology developments.
  - Evaluated applicability of promising information extraction and link discovery techniques.
  - Selected candidate information extraction techniques and approaches for development.
  - Selected candidate link discovery techniques for development.
  - Selected candidate pattern learning techniques for development.
  - Demonstrated the ability to acquire and use non-traditional data sources to perform surveillance during the 2001 Presidential Inaugural celebration activities.
  - Demonstrated alerting and abnormal disease detection performance based on seeding the indicator data with hypothetical events.
  - Identified abnormally high levels of naturally occurring diseases using non-traditional data sources.

- Wargaming the Asymmetric Environment. ($6.863 Million)
  - Developed and cross-validated an asymmetric model ontology with open and classified data.
  - Statistically tested an initial set of advanced reasoning techniques for applicability to predicting an asymmetric adversary's behavior.
  - Developed initial predictive models for a set of specific known and existing asymmetric adversaries.
  - Conducted initial and successful predictive modeling experiments.
  - Transitioned baseline predictive models to operational partners.

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

- Human Identification at a Distance. ($15.850 Million)
  - Incorporate additional sensors and biometrics into the pilot force protection system.
  - Evaluate and demonstrate the prototype advanced human identification system at force protection and homeland defense sites.
  - Identify the limits of range, accuracy, and reliability on combinations of facial features, gait, and other key identification techniques and determine the critical factors that affect the performance of biometric components.
  - Continue the development of the most promising biometric technologies based upon experimental evaluation performance.
  - Develop methods and algorithms for fusing multi-modal biometric technologies and deriving biometric signatures.

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- Evidence Extraction and Link Discovery. ($ 14.398 Million)
  - Specify models of asymmetric threat scenarios.
  - Develop and establish baseline performance for information extraction techniques for extracting geographical, organizational, and transactional relationships from text messages, news reports and web pages.
  - Develop ability to discover relevant connections between entities of the same type.
  - Develop ability to learn patterns corresponding to threat models comprising connections of single-type entities (e.g., people to people, or sets of related financial transactions).
  - Implement prototype demonstration of maturing EELD tools and techniques with DoD partners for potential transition opportunity of technologies for near-term support.
  - Develop a repository schema convention, simplified query language, information sharing rules, and peer-to-peer architecture to enable rapid creation of large, distributed information repositories.

- Wargaming the Asymmetric Environment. ($15.839 Million)
  - Establish operational testbeds in conjunction with one or more transition partners (DIA, Joint Staff, and others).
  - Extend predictive model development to finer levels of details of tactic, target, location, and timeframe characteristics.
  - Develop predictive models for specific and existing individual and group adversaries.
  - Generalize predictive models from a single adversary to multiple adversaries (asymmetric classes).
  - Conduct generalization experiments to empirically define classes of asymmetric threats by common predictive factors.
  - Continue to test and validate threat specific models and modeling techniques.
  - Transition new and revised predictive models to operational partners.
  - Expand predictive modeling to Operations Other Than War (OOTW) context.

- Bio-Surveillance. ($8.000 Million)
  - Collect and analyze historical epidemiological data for normal diseases in order to model detectors for abnormal events.
  - Develop possible concepts for a bio-surveillance system and identify possible components and apply these capabilities in a system to detect bio-surveillance activity within the national Capital Region.

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– Develop computer simulation environment to emulate bio-terrorist events and impacts on agricultural, animal and human populations.
– Identify, access, and analyze additional data sources.

- Endstate. ($2.000 Million)
  – Investigate reduced order modeling techniques for cross network effects prediction.
  – Identify technology for modeling adversary work-arounds.
  – Investigate methods for maintaining timely and accurate network state estimates.

- DefenseNet. ($2.000 Million)
  – Characterize DoD information and communications systems requirements in contrast to commercial Internet models (e.g., peer to peer).
  – Assess the security implications of candidate optical / electronic network architectures (protocols, management and routing).

(U) <u>FY 2003 Plans:</u>

- Human Identification at a Distance. ($14.500 Million)
  – Develop multi-modal HumanID technologies and extend the prototype advanced human identification system by adding two additional biometric modalities.
  – Continue to develop biometric fusion algorithms to include up to five biometric components.
  – Conduct multi-modal fusion experiments and performance evaluations.
  – Demonstrate advanced human recognition capabilities in multiple force protection or homeland defense environments.

- Evidence Extraction and Link Discovery. ($14.000 Million)
  – Demonstrate integrated extraction capability for all relationship types from all source types, including rapid adaptability to new types of relationships and new data sources.
  – Develop ability to detect instances of patterns comprising multiple entity types with multiple types of connections.
  – Develop ability to learn patterns comprising connections of multiple entity types with multiple types of connections.
  – Conduct performance evaluation of all capabilities and model performance of combined capabilities.

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- Develop ability to extract links and relationships from processed textual summary of information obtained from streaming (audio/video), imagery, and sensor data.

- Wargaming the Asymmetric Environment. ($18.500 Million)
  - Perform operational tests through the development and validation of predictive models.
  - Perform predictive comparisons between the current analytical models and the WAE modified analytical model.
  - Extend predictive techniques to develop sequences of behaviors (emulation) for specific and classes of adversaries.
  - Perform operational tests through the development and validation of emulation models.
  - Transition new and revised predictive models to operational partners.
  - Integrate predictive technologies into an automated indication and warning system.
  - Beta test automated indication and warning system in conjunction with operational partners DIA, Joint Staff, etc.

- Bio-Surveillance. ($13.500 Million)
  - Refine emulation environment with updated data sources, sensors, data monitoring software models, and detection algorithms.
  - Develop initial signal detection algorithms.
  - Develop a privacy protecting agent architecture for the integration of heterogeneous data systems.

- Genisys. ($11.000 Million)
  - Develop a database schema crawler for discovering the structure of existing databases, tools for term translation, and automated generation of new schema to enable current databases to be integrated semi-automatically.
  - Develop methods of re-structuring semi-structured or natural language information sources.
  - Create, test, and experiment with a prototype repository that integrates five or more existing databases and semi-structured information sites.

- Mis-Information Detection and Generation (MIDGET). ($6.500 Million)
  - Develop domain specific indicators of potential intentional mis-information in open source material using “Red-Team” wargaming techniques and expert knowledge.

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– Explore combinations of techniques from linguistic genre analysis, learning with background knowledge, business process modeling, and adversarial plan recognition for detection of intentional mis-information in open sources.

(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 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	47.876	65.561	60.000	50.966	48.520	47.444	44.384	Continuing	Continuing
Networked Embedded Systems Design AE-01	8.850	18.191	22.000	25.443	24.746	27.676	24.658	Continuing	Continuing
Software for Autonomous Systems AE-02	13.757	23.896	26.000	10.926	9.906	9.884	9.863	Continuing	Continuing
Software for Embedded Systems AE-03	17.288	23.474	12.000	14.597	13.868	9.884	9.863	Continuing	Continuing
Gigabyte Applications AE-04	7.981	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

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

(U) Embedded computing provides the connection between the physical world and computation realm. Embedded computing impacts the superiority of a multitude of DoD systems from avionics to smart weapons. Virtually all-new weapon systems from the F-22 aircraft to National Missile Defense and from the Future Combat System to Unmanned Combat Air Vehicles depend on embedded software technology. The level of software complexity in these systems is unparalleled. The goal of the Embedded Software and Pervasive Computing program is to greatly extend the reach and effectiveness of computation from mainframes and desktops into the physical world. These embedded programs pursue the software and systems research to facilitate a new emerging application of computers, and conduct research to greatly increase the autonomy of those systems, so as to promote the human role from that of operator to supervisor thereby reducing the mission demand for intensive manpower. Embedded system advancements may revolutionize system and software technology to facilitate the efficacy of the integrated battlefield.

(U) The Networked Embedded Systems Design project will extend DoD's ability to monitor and control the physical environment and will require a much "deeper" approach to information systems – one that manages the vast quantities of "physical" information that can be accessed by sensors and actuators in direct contact with real world processes. To enable this transition, both the network and embedded software infrastructure must be extended to deal with: challenges created by a wide diversity of embedded devices dealing in physical world information which must be

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addressed by network research; vast increases in the numbers of nodes with real-time transmission requirements; and operating regimes in which network-based nodes must host services on behalf of embedded clients. Research on embedded software creation must radically extend the technology to enable the composition of software systems subject to physical constraints.

(U) The Software for Autonomous Systems project develops software to enable predictable, safe, and cooperative operation of free ranging, autonomous systems. This effort includes software for selected mobile robots performing tasks in dynamic, unstructured (physical) environments without the need for synchronous, operator control inputs or high quality communications links. This effort also includes the development of advanced computer-based control systems to improve the capabilities of manned and unmanned aircraft. Advanced control system development will exploit recent breakthroughs in hybrid systems research, which combines continuous-time systems with discrete event systems.

(U) The Software for Embedded Systems project develops a new class of software to deal with the processing of physical world information by embedded devices. The convergence of processing power, vanishing size and decreasing cost of today's microprocessors has created new devices and micro-sensors that enable a new wave of DoD applications. The effort includes new algorithms and software that enable distributed micro-sensor networks to rapidly and accurately detect, classify, and track threats and events of interest in the battlefield. The effort also includes new technology to make changes in complex software systems predictably to ensure the safety and reliability of critical military systems.

(U) The Gigabyte Applications project was initiated to develop technology to enable robust operation of DoD's mission-critical systems and platforms that are inherently geographically dispersed and are dependent on extremely high data flows. Capabilities for end-applications to tie in with other applications as well as with signals from multiple hardware sources and with human users were developed with technologies that allow ultra high-throughput, sustained low-latency data delivery and processing. Funding for this effort ended in FY 2001.

(U) **Program Change Summary:** (*In Millions*)	**FY2001**	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	52.407	75.561	62.000
Current Budget	47.876	65.561	60.000

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(U) Change Summary Explanation:

FY 2001 Decrease reflects the SBIR reprogramming and minor program realignments.
FY 2002 Decrease reflects congressional program reduction.
FY 2003 Decrease reflects reprioritization of Agency requirements.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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COST (In Millions)	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Networked Embedded Systems Design AE-01	8.850	18.191	22.000	25.443	24.746	27.676	24.658	Continuing	Continuing

(U) **Mission Description:**

(U) This project will extend DoD's ability to build complex embedded software systems, which are the primary source of superiority in modern weapons platforms. Embedded software monitors and controls the physical environment, and lends intelligent behavior to platforms. The design and implementation of embedded software systems require an in-depth approach to information systems. Embedded systems will manage the vast quantities of physical information that can be accessed by sensors and actuators in direct contact with the real world. To enable the design of these tightly integrated physical and information systems, network and software infrastructures must be extended to interact with a wide diversity of physical world devices and environments. Designs will accommodate vast increases in the numbers of nodes with real-time data requirements, and must support operating regimes in which network-based nodes must host services on behalf of embedded clients. Research on embedded software creation must radically extend the technology to enable the modular composition of software systems subject to physical constraints.

(U) The Model-Based Integration of Embedded Systems (MoBIES) component will facilitate tools to design and test complex computer-based systems such as avionics, weapons, and communications systems. It will simplify the design of complex embedded systems by focusing on the pre-production environment rather than after-the-fact integration. The approach is to customize the design tools used by applications engineers so that controller design and systems integration can be more fully automated and the errors thereby reduced. The technology will formalize system modeling and programming tools in a common mathematical form. This analysis will allow integrated design of hardware and software from the earliest stages in system development, leading to interoperable tools, automatic systems integration, and simplified test and evaluation. The MoBIES program will allow such custom-designed toolsets to be easily tailored to specific applications, resulting in more efficient, verifiable, scalable, and re-usable programs for complex weapon and vehicle systems applications. Its objectives are to increase by 100% the size of the embedded software programs that existing tools can reliably produce, and decrease by 80% the design time necessary to create application-specific tools.

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(U) The Adaptive and Reflective Middleware Systems (ARMS) program will focus on mission-critical distributed embedded systems where different levels of service are possible and desirable under different conditions and costs; the levels of service in one dimension may need to be coordinated with and/or traded off against the levels of service in other dimensions to achieve the intended overall result. Autonomous system behavior requires the middleware components and frameworks to adapt robustly to quantifiable changes in environmental conditions. In ARMS, middleware will be responsible for coordinating the exchange of information efficiently, predictably, scalably, dependably and securely between remote entities by using advanced Quality of Service capabilities of the underlying network and endsystems.

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

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

- Model-Based Integration of Embedded Software. ($ 8.850 Million)
  - Developed modeling tools that can manage overlapping modeling views.
  - Investigated methods for the mathematical modeling and composition of model-based software generators.
  - Developed customizable design frameworks for embedded software.
  - Demonstrated the rapid synthesis of embedded systems using customizable frameworks and model-based code generators.
  - Developed meta-modeling techniques for integrating different commercial off-the-shelf analysis tools into a single tool environment.

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

- Model-Based Integration of Embedded Software. ($13.191 Million)
  - Develop methods to integrate different models of computational processes for different applications.
  - Develop methods for efficient run-time checking for models of computation.
  - Demonstrate ability to propagate different physical constraints among modeling views.
  - Demonstrate ability to coordinate different design aspects across modeling perspectives.
  - Develop hybrid (continuous and discrete) modeling and analysis techniques for embedded systems.
  - Develop generic components for model-based software generators.

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- Develop and demonstrate techniques for the mathematical modeling and formal verification of software generators.
- Develop formal models for synchronous embedded software frameworks.
- Demonstrate end-to-end tool integration in avionics and vehicle electronics experimental platforms.

• Adaptive Reflexive Middleware Systems. ($5.000 Million)
- Develop adaptive protocols, algorithms, patterns, and tools for distributed resource management.
- Develop meta-programming policies and mechanisms to customize quality of service enabled middleware services and applications.

(U) <u>FY 2003 Plans:</u>

• Model-Based Integration of Embedded Software. ($17.000 Million)
- Demonstrate ability to dynamically combine distributed components with different models of computation.
- Develop tools for automatically checking safety and reliability properties of automatically generated software.
- Develop techniques for customizing real-time operating systems according to application domains.
- Investigate methods for the mathematical modeling and composition of model-based software generators.
- Develop customizable frameworks for the design of embedded software.
- Demonstrate the rapid synthesis of embedded systems using customizable frameworks and model-based generators.
- Develop techniques for integrating different commercial off-the-shelf analysis tools into a single tool environment.
- Develop and demonstrate the use of multiple view modeling techniques for military avionics and combat vehicular electronics applications.

• Adaptive Reflexive Middleware Systems. ($5.000 Million)
- Develop formalized design expertise (pattern languages) for generating Quality of Service-enabled middleware frameworks and application components.
- Develop reflective techniques for synthesizing optimized real-time and embedded middleware.

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(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Software for Autonomous Systems AE-02	13.757	23.896	26.000	10.926	9.906	9.884	9.863	Continuing	Continuing

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

(U) This project develops revolutionary control technology to enable predictable, safe, and cooperative operation of free ranging, autonomous systems. DoD needs revolutionary new capabilities for increasing autonomy of weapon systems. Increased autonomy will enable combined manned and unmanned warfare, and the extensive use of robotics technologies empowers future warfighters to accomplish their missions more effectively with less risk of casualties, preserving the U.S. military's most important resource. The project builds on major advancement in computing and software during the past decade, which makes the practical application of complex nonlinear, hierarchical control techniques feasible.

(U) The Common Software for Autonomous Robotics component of this project will develop software technologies for large groups of extremely small and highly resource constrained micro-robots, enabling the coordinated action of many robots to achieve a collective goal while allowing the operator to task and query the ensemble of robots as a group, rather than as individuals. This component addresses four critical areas: (1) coordinated behaviors, including both explicit control strategies that decompose tasks and propagate instructions to individual elements, and implicit control strategies analogous to potential fields; (2) inter-robot communications, including networking protocols that minimize energy consumption and novel alternative communications strategies such as insect-like "pheromone" communications; (3) computational architectures ranging from fully distributing the processing among the micro-robots themselves to off-loading the processing to a separate "proxy" processing resource; and (4) human-robot interfaces, including both explicit (symbolically grounded) and novel implicit (non-symbolic) user interface technologies. The payoff will be distributed "swarm" systems of robots that effectively exploit the scalability of large numbers to robustly perform important military tasks such as area surveillance and mine clearing.

(U) The Software Enabled Control component leverages growth in computing and software technologies to improve the capabilities of control systems for advanced manned and unmanned aircraft. The challenges are to mathematically model complex changes in flight conditions and vehicle status, to design fast digital control systems to automate aggressive maneuvers, to automatically detect and recover from faults or damage, and to provide a common computing platform and programmer's interface for real-time implementations of these methods on a variety of vehicles. Advanced control system development will exploit recent successes in hybrid systems research, which combines continuous-time systems with randomly occurring discrete events. Hybrid systems can then adapt to sudden changes such as aerodynamic disturbances, threat conditions, damage

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or failure, or limits in the flight envelope. The software to implement these controls must manage these events and guarantee stable operation throughout the execution of the mission. The Software Enabled Control component will provide fast, reliable automation and failure recovery for flight control systems in manned and unmanned aircraft both fixed- and rotary-winged.

(U) The Automated Light Transport Aircraft (ALTA) Control Systems component will provide the integrated vehicle management and control system technology to enable small VTOL (vertical takeoff and landing) air vehicles to serve as "personal" delivery vehicles in logistics and combat support operations.

(U) The Agent Based Negotiation component developed technologies for the autonomous operation of large collections of agents negotiating real-time resource allocation issues, such as those encountered in logistics and countermeasures.

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

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

- Common Software for Autonomous Robotics. ($4.114 Million)
  - Performed experimental evaluation of networking protocols for distributed robot controls that are more energy efficient than conventional implementations.
  - Performed prototype demonstration and experimental evaluation of software for distributed robotics capable of coordinating the operation of 10+ robotic devices in a collective task.

- Software Enabled Control. ($8.736 Million)
  - Completed prototype implementation of multi-mode control architectures and frameworks.
  - Developed a predictive active model framework to anticipate changing conditions.
  - Developed parametric predictive and adaptive control frameworks.
  - Completed multi-level, multi-modal advanced design tools.
  - Demonstrated real-time adaptive control through Open Control Platform (OCP).
  - Integrated OCP on laboratory vehicle.

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- Agent Based Negotiation. ($ 0.907 Million)
  - Completed prototype demonstration of autonomous software's ability to utilize negotiation in logistics scenario.

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

- Common Software for Autonomous Robotics. ($6.814 Million)
  - Demonstrate energy-saving protocols with at least 70 percent savings over conventional protocol implementations.
  - Integrate developmental network protocols into selected distributed robotic platforms and evaluate in the indoor application domain.
  - Integrate natural, implicit communications modes and user interface into selected distributed robotic platforms
  - Investigate cooperative approaches to achieving critical situational awareness in the indoor application domain.
  - Assess coordination and fusion of multiple sensing modalities with computational processing to achieve real time operation.

- Software Enabled Control. ($17.082 Million)
  - Develop Open Control Platform (OCP) services for control coordination of unmanned avionics (e.g., mode switching; event generation; discrete blocking, enabling, forcing).
  - Configure OCP prototype for three-level hybrid (discrete + continuous) control.
  - Integrate hybrid Fault Detection Identification Reconfiguration framework on OCP.
  - Integrate asynchronous hybrid control on OCP for multi-system coordination.
  - Release beta prototype framework for multi-system hybrid control coordination platforms.
  - Integrate predictive active services, control parameterization, hybrid stability, and transition management framework on OCP.
  - Develop system concept for high-confidence authority management for hybrid control.
  - Develop theoretical framework for robust hybrid control.
  - Conduct simulation experiments for two-level control; conduct flight experiment.
  - Plan integrated flight experiment on fighter aircraft and unmanned vehicles.
  - Develop baseline sensor and actuator resource services for unmanned aerial platforms.

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(U) FY 2003 Plans:

- Common Software for Autonomous Robotics. ($4.000 Million)
  - Conduct field experiments using selected distributed robot platforms.
  - Demonstrate realistic mission scenarios using representative platforms in a simulated mission context.
  - Develop coordinating techniques between cooperating platforms to support accelerated mobility and reconnaissance.
  - Develop shared representations to support collaborative communication between humans and robotic systems.

- Software Enabled Control. ($18.000 Million)
  - Integrate coordinated hybrid system services into Open Control Platform (OCP) middleware, useable across several military avionics platforms.
  - Integrate multi-system hybrid prediction and transition control into OCP.
  - Integrate active state model data services into OCP.
  - Integrate software customization and sensor/actuator resource services into OCP.
  - Lab demonstration of coordinated flight with coupled system dynamics.
  - Demonstrate integrated controller with active state modeler and fault reconfiguration strategies.

- Automated Light Transport Aircraft (ALTA) Control Systems. ($4.000 Million)
  - Develop digital flight control systems for “personal” Vertical Take-Off and Landing vehicles.
  - Automate cockpit control to perform high-speed, low altitude nape-of-earth maneuvers with minimal piloting.
  - Synthesize integrated situation awareness displays from passive sensing and telemetry in order to reduce vehicle signature.
  - Transform robust control principles into safe, certified avionics systems.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Software for Embedded Systems AE-03	17.288	23.474	12.000	14.597	13.868	9.884	9.863	Continuing	Continuing

(U) Mission Description:

(U) This project develops a new class of software to deal with mobile, distributed sensor networks and the processing of physical world information by embedded devices. The convergence of processing power, vanishing size and decreasing cost of today's microprocessors has created new devices and micro-sensors that enable a new wave of DoD applications. The effort includes new algorithms and software that enable distributed micro-sensor networks to rapidly and accurately detect, classify, and track threats and events of interest in the battlefield. The effort also includes new technology to make changes in complex software systems predictably to ensure the safety and reliability of critical military systems.

(U) The Large Scale Networks of Sensors component is comprised of the Sensor Information Technology (SensIT) program which develops new algorithms and software that enable distributed micro-sensor networks to rapidly and accurately detect, classify, and track threats and events of interest in the battlefield, including reconnaissance, surveillance, and tactical applications. New technology challenges include robust, reliable, low-latency networking methods than can scale and provide rapid ad hoc networking of fixed and mobile devices. Another challenge is to develop energy efficient algorithms for in-network collaborative processing required to convert multi-modal sensor data to useful information. Additionally, remote querying and accessing data and information collected by the sensor network, by multiple users, should be simple, with easy to use interfaces. The program develops new ad hoc networking strategies based on diffusion methods that achieve application-specific connectivity, as traditional internet protocols are not effective for large sensor networks. A distributed micro-database approach is being developed for collecting and storing data, as well as to support dynamic querying and tasking of sensors through a simple language that enables users to access geo-referenced events, hiding unnecessary detail. Finally, the algorithms and software are being integrated, with iterative design refinement and technology demonstration through field-experiments jointly conducted with the military.

(U) The Dynamic Assembly for Systems' Adaptability, Dependability and Assurance (DASADA) Program goal is "self healing" systems. Technology is being developed to automatically insert measurement probes and gauges into running (software) systems -- allowing them to judge their health and status. Complementary technology will allow the systems to automatically reconfigure themselves to "fix" problems. Major technical challenges include developing technology to: 1) Precisely determine and usefully specify the allowable variation in components and their composition; and, 2) Measure that components fit together as systems change, within functional and non-functional tolerances permitted by

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dynamically evolving system requirements. The DASADA Program will enable developers and implementers to make changes in complex software systems predictably to ensure the safety and reliability of critical military systems.

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

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

- Large Scale Networks of Sensors. ($12.590 Million)
  - Implemented experimental prototype supporting automated aggregation and distribution of sensor-derived information involving at least 50 nodes and 100 sensors.
  - Evaluated methods for efficient interoperation of fixed and mobile sensors.
  - Demonstrated multi-node sensor network software and benefits of collaborative signal processing for military operations such as ground moving target detection.
  - Developed prototype for declarative interfaces for tasking and querying of multi-taskable sensor networks.
  - Testing and demonstration at Twenty-nine Palms, U.S. Marine Corps, included applications for detector/tracker cueing an imager; mobile query from an Unmanned Air Vehicle seismic tracking.

- Dynamic Assembly for Systems Adaptability, Dependability and Assurance (DASADA). ($4.698 Million)
  - Conducted preliminary demonstrations of dynamic software component composability with multiple standard communication (e.g. Distributed Component Object Model, Common Object Request Broker Architecture, Distributed Computing Environment) or structuring (e.g., Extended Markup Language, Resource Description Framework, Document Object Model) infrastructures.

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

- Large Scale Networks of Sensors. ($14.592 Million)
  - Optimize embedded node processing and protocols to minimum latency in sensor networks.
  - Integrate candidate protocols for interoperation between fixed sensor devices and mobile devices, for lab and field evaluation.
  - Implement distributed algorithms for sensor coverage, and easy graphical user interface, to support real-time incremental deployment in battlefield contexts.

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- Implement algorithms for application-specific distributed computing software for collaborative signal processing including detection, classification, and tracking for a range of military applications.
- Implement efficient ways to fuse information at various levels in the network to support collaborative signal processing and to facilitate extraction of timely information from the sensor network.
- Implement technology for dynamic tasking, querying, multi-tasking, and rapid specialization, customization, and reconfiguration of software during operation, through mobile code technology.
- Develop modeling and simulation capability scalable to large sensor networks.
- Develop design principles for deployment of sensor networks in specific DoD contexts, including determination of the right network size, density of nodes, sensor suite, node and link capacity.
- Conduct field demonstrations to show new technology capabilities of embedded distributed micro-sensor software for tracking of mobile targets, and detection and classification of threats in battlefield scenarios. This will include 'Steel Knight' exercise with U.S. Marine Corps, and imaging for target validation.
- Engage Intelligence, Emergency, and National Guard end users in joint experimentation to demonstrate new paradigms for sensing threats.

• Dynamic Assembly for Systems Adaptability, Dependability and Assurance (DASADA). ($8.882 Million)
  - Demonstrate a "toolkit" of software components/gauges to:
  - Determine the suitability of components for insertion / (re)use in a given system.
  - Enable safe run-time composition and deployment.
  - Enable continual monitoring of the system to guide adaptation.
  - Ensure that critical (user defined) properties are maintained during and after composition, adaptation and deployment.
  - Solicit inputs from DoD agencies to conduct experiments based on planning efforts and preliminary demonstrations.
  - Identify most promising technologies for experiment transition.

(U) <u>FY 2003 Plans:</u>

• Dynamic Assembly for Systems Adaptability, Dependability and Assurance (DASADA). ($12.000 Million)
  - Conclude Phase I, technology refinement and integration projects.

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– Fifteen programs are currently evaluating DASADA technology with respect to their needs – two to three of these will be selected to conduct experiments that quantify benefits resulting from use of DASADA technologies. The programs include:
-- Theatre High Altitude Area Defense to provide assured dynamic system adaptability and real time defense planner updates.
-- U.S. Pacific Command's Geoworlds system to provide more rapid installation, deployment, and continual adaptation with guarantees of overall operational effectiveness
-- Space and Naval Warfare Systems Command's Managed Information and Network Exchange Router to provide more predictable results when replacing system components and improved ability to detect when performance is violating constraints.
-- Infosphere Situational Awareness Master Caution Panel to provide monitoring tools that operate in component based (rather than conventional client/server) environments.
-- USAF AWACS 40-45 block upgrade to provide distributed Client/Server systems with real-time error recovery / reconfiguration capabilities that have defied current technology solutions.
-- Aerospace Command, Control, Intelligence, Surveillance, and Reconnaissance Center, Air Operations Center to provide improved capabilities to upgrade software components and integrate commercial off-the-shelf components in a reliable manner.

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

- Not Applicable.

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

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Biological Warfare Defense PE 0602383E, R-1 #16				
COST *(In Millions)*	FY 2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	146.216	146.680	133.000	142.000	140.000	140.000	140.000	Continuing	Continuing
Biological Warfare Defense Program BW-01	146.216	146.680	133.000	142.000	140.000	140.000	140.000	Continuing	Continuing

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

(U) DARPA's Biological Warfare Defense project is budgeted in the Applied Research Budget Activity because its focus is on the underlying technologies associated with pathogen detection and remediation. This project funds programs supporting revolutionary new approaches to biological warfare (BW) defense and does not duplicate efforts of other government organizations.

(U) Efforts to counter the BW threat include developing barriers to block entry of pathogens into the human body (including unique methods for rapid air and water purification), countermeasures to stop pathogen and chemical consequence and to modulate host immune response, medical diagnostics for the most virulent pathogens and their molecular mechanisms, biological and chemically-specific sensors, advanced decontamination and neutralization techniques, consequence management tools, and integrated defensive systems. Program development strategies include collaborations with pharmaceutical, biotechnology, government, and academic centers of excellence.

(U) Pathogen countermeasures (e.g., Anti-Virals/Immunizations, Anti-Bacterials/Anti-Toxins, Multi-Purpose, and External Protection) under development include: (1) multi-agent therapeutics against known, specific agents and (2) therapeutics against virulence pathways shared by broad classes of pathogens. Specific approaches include developing a new class of antibiotics targeted to enzymes essential to bacterial pathogen survival, identification of virulence mechanisms shared by pathogens, development of therapeutics targeting these mechanisms, efficacy testing in cell cultures and animals, and advanced non-toxic decontamination strategies. The development of an artificial immune system through 3- dimensional tissue engineering will provide rapid, in vitro assessments of novel countermeasures against unique DoD threat agents.

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(U) In the early stages, many illnesses caused by BW agents have flu-like symptoms and are indistinguishable from non-BW related diseases. Early diagnosis is key to providing effective therapy. The advanced diagnostics efforts will develop the capability to detect the presence of infection by biological threat agents, differentiate them from other pathogens (including those of non-BW origin), and identify the pathogen even in the absence of recognizable clinical signs and symptoms (i.e., while the pathogen numbers are still low).

(U) The ability to rapidly detect biological warfare agents on the battlefield with a low false-alarm rate is a crucial requirement. To address this need, the program is creating more efficient and effective miniature sampling technologies that concentrate contaminated air and enhance the ability to capture biological warfare agents. The program is developing a new range of antibodies and “designer small molecules” to bind specific agents (to replace the lower affinity antibodies currently used). A biosensor based on universal probes is being developed for detecting known and possibly bio-engineered pathogens, as an environmental sensor and a diagnostic tool. The use of fluids as a requirement for biological agent detection is also being eliminated and replaced by a miniaturized time-of-flight mass spectrometer. Development of a bacterial biochip to identify genus and species without multiplying the DNA by the polymerase chain reaction (PCR) is also under development, thereby potentially saving over half the time required for identification. Additional efforts are focusing on standoff biological/chemical sensors, as well as the construction of molecular, cellular, and multicellular sensors for the rapid detection of biological threats. These cellular and tissue-based sensors have the ability to respond to both known and unknown threats, determine live vs. inactivated threat status, and report functional consequences of exposure (mechanisms of action). The use of organisms such as insects is also being explored as information collectors for environmental biological or chemical threats. A variety of applications for these sensors are being explored including protection of buildings from a biowarfare agent attack as well as novel surveillance systems for non-battlefield environments.

(U) DARPA is developing technologies for integrated defensive systems to be employed in military buildings to protect inhabitants and to enhance the capability to decontaminate exposed surfaces. The approach is to modify and augment the infrastructure of buildings to allow them in real-time to sense and defeat an attack by bio or chem agents. The program has three goals: to protect the human inhabitants from the effects of the agents; to restore the building to function quickly after the attack; and to preserve forensic evidence for treatment of victims, if necessary, and for attribution. The DARPA focus is on the challenging problem of protection from internal releases of agent, where active and timely control of airflow is required to prevent a building’s HVAC system from spreading the agent throughout the building. To enable such building-protection systems, DARPA is pursuing low-pressure-drop filters, advanced decontamination and neutralization techniques, and fate and transport models to predict agent location and lethality. In addition, DARPA is investigating the systems-level issues of integrating and optimizing such active systems, as well as portal-barrier technologies to prevent the introduction of agents into facilities. These efforts will use full-scale test facilities to determine the effectiveness of protection components and to experiment with various strategies and architectures for protection. These experiments will be

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followed by systems design and optimization, initially targeted at the most proliferated threats and then progressing to more challenging future threats. This effort will culminate with a full-scale demonstration of a complete building protection system at a military installation and will leave behind a software tool for the design and optimization of building-protection systems for other military buildings.

(U) The Biological Warfare Agent (BWA) Surveillance Techniques program will develop and demonstrate effective and efficient BWA surveillance systems for urban environments, such as military bases and transportation centers, to detect a covert aerosol release of a BWA and to determine the approximate release location *before the onset of symptoms in humans*. The program will investigate the key architecture trades, including: the appropriate mix of stationary and mobile assets (collectors/samplers and identification sensors); the value of distributed sampling and identification (sensing) versus distributed sampling with centralized identification; the role of layered sensing, such as continuous wide-area surveillance followed by focused/targeted collects for confirmation; the importance of spatial and temporal resolution in enabling backtracking to determine release time and release location; and specialized collection and identification requirements in different environments. These trades will be carried out by modeling covert releases and then analyzing the ability of various architectures (1) to detect the release quickly and (2) to geo-locate the source. System cost and complexity will also be evaluated, and baseline background data will be collected. After the evaluation of candidate architectures, the program will develop a system design; develop the components (samplers, sensors, networking, and algorithms) as required; build and integrate the surveillance system; and demonstrate overall system performance.

(U) Mission effectiveness requires rapid, correct medical responses to biological weapon threats or attacks. This project has provided comprehensive protocols to protect or treat combatants by using current and emerging biological countermeasures. It provided accelerated situational awareness for biological warfare events by detecting exposure to agents through an analysis of casualty electronic theater medical records and located and determined the most effective logistical support for providing appropriate treatment and pathogen-specific resources required to mitigate effects of the attack. The last year of funding for this effort was FY 2001.

(U) DARPA worked with a number of governmental organizations to exploit recent advances in high throughput genetic sequencing to obtain complete genetic information on a number of important pathogens and their non-pathogenic nearest neighbors. This allowed development of an inventory of genes and proteins that distinguish pathogens from non-pathogens and to identify pathogenic markers in any guise. This information will be used to provide superior molecular targets and enable new generations of detectors, diagnostics, and therapeutics. Funding completed for this program in FY 2001.

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(U) The DNA Chip Technology Research program investigated the value of a new concept of "data mining" using the repetitive sequence-based polymerase chain reaction (PCR) patterns from a large data of biowarfare agents and the feasibility of using this approach on high-density microchips.

(U) DARPA also explored non-traditional approaches to desalination and evaluated the potential of delivering immune system enhancement via inhalation for defense against BW threats.

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

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

- Anti-Virals/Immunizations. ($20.300 Million)
  - Tested and validated (in-vivo) a method of mucosal immunization based upon high level expression of pathogen antigens and epithelial transport molecules in edible transgenic plant products.
  - Tested and validated (in-vivo) the protective efficacy of vaccines and antibodies produced by plant cells against pathogens.
  - Demonstrated efficacy of the rapid and efficient delivery of pathogen antigens via new genetic vaccine vectors.
  - Demonstrated (in-vivo) the rapid design and development of new vaccines (or therapeutics) against unidentified or unknown pathogens.
  - Demonstrated broad-spectrum strategies with potential for immunomodulatory activity against multiple pathogens.

- Anti-Bacterials/Anti-Toxins. ($20.647 Million)
  - Demonstrated surface expression of specific enzyme molecules for the rapid inactivation of various pathogens.
  - Demonstrated (in-vivo) the efficacy of a broad-spectrum bacterial pathogen antagonist.
  - Validated (in-vivo) broad spectrum, superantigenic, anti-toxin antagonists and vaccines.
  - Demonstrated (in-vivo) efficacy of broad spectrum, superantigenic, antitoxin antagonists and vaccines.

- Multi-Purpose. ($21.833 Million)
  - Developed therapeutic strategies against bioregulators and other mid-spectrum agents.

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- Demonstrated synthetic polymer complements for pathogenic antigens and virulence factors.
- Developed therapeutic strategies for minimizing harmful immune responses to biological warfare agents.
- Demonstrated (in-vitro) the efficacy of monomeric and dimeric DNA and RNA binding molecules as novel countermeasures against multiple pathogens.
- Validated polyvalent inhibitors for blocking pathogens on the surface of target cells in-vivo.
- Identified superantigen antagonist for broad protection against biological warfare agents with minimal side effects.
- Validated (in-vivo) the efficacy of subcellular pathogen response imaging for rapid detection.
- Validated technologies broadly applicable to enhance cellular therapeutics (delivery platforms) and virulence modulation (intracellular and inflammatory cascades).

- External Protection. ($10.600 Million)
  - Developed a novel architectural approach for the manufacture of materials that are effective in blocking pathogens and limiting disease.
  - Demonstrated a non-aqueous advanced decontamination method.
  - Demonstrated a water purification system effective against a range of biological agents (including toxins and bioregulators).
  - Tested initial performance of advanced sorbent materials for the purification of air contaminated with CW and BW agent simulants for individual protection.
  - Built and tested a prototype air purification system for collective protection for a group of soldiers.
  - Began testing a prototype protective system against non-virulent biological warfare agents, bio-toxins and regulators.

- Advanced Diagnostics. ($12.681 Million)
  - Tested probe panels in relevant sample types including strategies for rapidly generating new/novel probes.
  - Demonstrated that sample collection and/or preparation techniques do not introduce artifacts.
  - Tested, in model systems, one or more of the most promising candidate strategies for rapid detection based on bodily responses or other biomarkers to provide early indication of infection or exposure.
  - Developed the capability to diagnose exposure to bio-regulator and mid-spectrum agents.
  - Demonstrated, in the laboratory, the feasibility of engineering red blood cells to detect and signal pathogen presence in the body.

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- Evaluated the feasibility of additional strategies (e.g., exhaled breath) for direct identification or detection of infection without direct sample collection.
- Demonstrated the ability to perform accelerated patient diagnosis using a rapid single molecule DNA sequencing technique in a model system.

- Sensors. ($25.800 Million)
  - Completed development and testing of first-generation prototype biochip sensor.
  - Continued the development of effective and rapid chip-reading capability with enhanced sensitivity and low false alarm rate.
  - Continued the development of advanced alternative technologies for live vs. dead bio-agent identification using peptides and other molecules.
  - Developed hierarchical biochip sensors.
  - Designed and tested techniques to replace antibody-based detection, such as short peptides, aptamers and lectins.
  - Designed and tested novel reporting/transduction techniques such as ion channels.
  - Designed and synthesized short peptide binding molecules for use in the detection of biological warfare agents.
  - Evaluated ion channel sensor systems for use in the detection of biological warfare agents.
  - Evaluated methods for removing micro-encapsulation of disguised pathogens and/or sensing through the micro-encapsulation.
  - Developed technologies required for next-generation miniature biological detectors including the use of microelectromechanical systems (MEMS), microfluidics, and mesoscopic-sized components.
  - Evaluated false positive and false negative rates for systems of detectors using biomolecular cells or tissues.
  - Exploited and/or mimicked the olfactory sensors of biological systems for use in the detection of biological warfare agents.
  - Demonstrated enhanced signal output from engineered cells and tissue based sensors and integrated information from these sensors with user interfaces for predictive responses.
  - Engineered a deployable prototype cell and tissue sensor for field-testing.
  - Evaluated sample collection technologies for cell and tissue sensors.
  - Evaluated methods of cell stabilization for possible application to cell based sensors.
  - Developed biosensor models and robust characterization protocols.
  - Evaluated new resonant modes for biosensors.
  - Investigated standoff techniques for trigger and identification.

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- Investigated critical design parameters for advanced biologically based BW sensors.
- Demonstrated use of organisms to collect chemical and biological warfare agents in the field.
- Developed and validated a comprehensive performance model for time-of-flight (TOF) mass spectrometer detection of aerosolized live agents against clutter.
- Evaluated time-of-flight (TOF) mass spectrometer performance for counter-proliferation scenarios.
- Initiated the development, modeling, and validation of integrated sensor systems designed to meet detailed threat specifications.
- Evaluated novel concepts for warning systems, including stationary or mobile-networked surveillance systems.
- Explored a novel concept (Triangulation ID for Genetic Evaluation of Biological Risks [TIGER] biosensor) for universal BW probes as a possible foundation for a new sensor suitable for forensics, biomedical surveillance and environmental sensing and estimated performance against bacteria.
- Explored the use of social insects as BW agent collectors.

• Bio/Chem Defensive Systems. ($13.105 Million)
  - Continued fate and transport model development in and around buildings and began experimental evaluation.
  - Continued to develop decontamination techniques appropriate for structures.
  - Evaluated novel low-pressure-drop, broadband filter technologies.
  - Developed neutralization technologies for aerosolized agents.
  - Conducted hazard assessment for protection of military buildings from bio-chem attack; assessed protection strategies.
  - Identified facilities, and identified/designed the facility modifications required, for full-scale testing and evaluation of building-protection systems.
  - Evaluated concepts for novel protection systems, such as portal barriers.

• Genetic Sequencing of Biological Warfare Agents. ($7.000 Million)
  - Completed the genomic sequencing of high-threat known and potential biowarfare agents.

• Consequence Management. ($6.000 Million)
  - Demonstrated Enhanced Consequence Management Planning and Support System (ENCOMPASS) management of multi-site BW incidents.

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- Demonstrated and fielded the use of ENCOMPASS for CONUS military force protection against BW attacks, i.e., Pacific Battlelab & Kernal Blitz Experiment.
- Transitioned ENCOMPASS components to Initial Detection Units of the Air Force and to PACCOM, JFCOM, and Wilford Hall Medical Center.
- Transitioned ENCOMPASS components into Joint Chiefs of Staff Operations Center.

• Asymmetrical Products for BWD. ($3.750 Million)
- Explored use of cytokines as biological warfare therapeutics.

• Desalination Research. ($ 3.000 Million)
- Evaluated non-traditional approaches to desalination.

• DNA Chip Technology Research. ($1.500 Million)
- Demonstrated feasibility of repetitive sequence polymerase chain reaction (PCR) on microchips.
- Demonstrated fingerprint profiling of anthrax strains.
- Determined "electronic barcodes" to distinguish closely related strains.

(U) **FY 2002 Plans:**

• Anti-Virals/Immunizations. ($18.500 Million)
- Assess feasibility of modeling viral RNA-protein structural interactions as a strategy to identify new targets for antiviral agents.
- Identify new target candidates for new classes of anti-viral agents.
- Demonstrate broad-spectrum therapeutic strategies against viral agents on the validated threat list, including smallpox.
- Determine the feasibility of using one or more animal systems as a means of developing data sufficient to provide regulatory guidance for the approval of newly developed anti-viral agents effective against verified BW viral threats.
- Test and validate (in-vitro) candidate antiviral therapeutic(s) developed by combinatorial chemistry for viral infections emanating from validated threats.

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- Test at least one candidate immunogen for mucosal immunization based upon high-level expression of pathogen antigens and epithelial transport molecules in edible transgenic plant products.
- Assess feasibility of strategies to develop edible multiagent vaccines.
- Assess feasibility of virally derived cytokine inhibitors as therapeutics for hemorrhagic fever viruses or other threat agents.
- Develop protocols to enable validated therapeutic products to transition to appropriate Service partner (e.g., USAMRIID).
- Develop strategies for Investigational New Drug (IND) enabling studies.
- Establish and validate common data set testing program for evaluation of transition candidate in standard models.
- Develop novel adjuvants to enhance vaccination, including anthrax, effectiveness.
- Transition shuffled antigen program for enhanced vaccine development to USAMRIID.
- Transition plant-based vaccine production program to USAMRIID.

• Anti-Bacterials/Anti-Toxins. ($18.500 Million)
  - Assess feasibility of identifying appropriate targets for anti-bacterial drug development by creating animal models innately resistant to infection.
  - Explore new concepts for identifying critical targets of host damage by pathogen (e.g., by development and use of animal models with engineered resistance, gene expression profiles).
  - Demonstrate both targeted and broad-spectrum therapeutic strategies against bacterial agents (e.g., anthrax).
  - Determine the feasibility of using one or more animal systems as a means of developing data sufficient to provide regulatory guidance for the approval of newly developed anti-bacterial agents effective against verified BW bacterial threats.
  - Test and validate (in-vivo) high-throughput screening technologies for bacterial infections emanating from validated threats.
  - Develop protocols to enable validated therapeutic products to transition to appropriate Service partner (e.g., USAMRIID).
  - Transition RNA-based discovery technology for drug target identification to USAMRIID.
  - Establish and validate common data set in-vivo qualifying systems for testing broad-spectrum anti-bacterial drugs.
  - Establish drug lead optimization program to facilitate transition process.

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- Assess the opportunity to extend window of effective treatment for late stage BW infection.

- Multi-Purpose. ($22.900 Million)
  - Test one or more candidate therapeutic strategies against bioregulator and other mid-spectrum agents.
  - Test (in-vivo) prototype monomeric and dimeric DNA and RNA binding molecules as novel countermeasures against multiple pathogens.
  - Identify novel opportunities to engineer metabolic response to threat agents.
  - Identify mechanisms for protection against catastrophic BW-induced shock.
  - Determine the feasibility of using one or more animal systems as a means of developing data sufficient to provide regulatory guidance for the approval of newly developed therapeutic agents effective against verified BW threats.
  - Demonstrate efficacy of subcellular pathogen response imaging for rapid detection.
  - Develop protocols to enable validated therapeutic products to transition to appropriate Service partner (e.g., immunomodulators).
  - Develop strategies for Investigational New Drug (IND) enabling studies.
  - Develop novel, bactericidal technologies for rapid post exposure treatment.
  - Evaluate ethyl-nitroso-urea (ENU) forward mutagenesis technology to create mouse lines that are resistant to BW infections.
  - Begin development of 3-dimensional printing culture system, including novel bioscaffolds for controlled development of artificial immune system.

- External Protection. ($8.180 Million)
  - Test a prototype air purification system for collective protection for a group of soldiers.
  - Demonstrate several individual water purification systems that can treat any biological, chemical or natural contaminant.
  - Demonstrate efficacy of individual air purification carrier technologies to reduce the pressure drop by one half, increase chemical warfare effectiveness factors (50 percent) and provide inherent HEPA filtration.
  - Test and demonstrate gas mask filter technologies against a full array of live BW and CW agents.
  - Demonstrate superior sorbent materials to adsorb CW agents and toxic industrial vapors.

- Advanced Diagnostics. ($18.000 Million)
  - Evaluate hyperspectral strategies for early clinical diagnosis of infection and other medical issues that affect soldier persistence.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Biological Warfare Defense PE 0602383E, R-1 #16

- Validate strategies for rapidly generating new probe panels for relevant sample types.
- Validate, in model systems, lead candidate strategies for rapid detection based on bodily responses or other biomarkers for early indication of infection or exposure.
- Evaluate multiplexed pathogen detection in microliter sample sizes.
- Explore new methods for rapidly sequencing DNA.
- Evaluate non-contact surface electrode for potential clinical applications.

• Sensors. ($30.000 Million)
  - Develop front end sampling modules for cell and tissue based biosensors.
  - Demonstrate utility of cell and tissue based biosensors in operationally relevant scenarios.
  - Identify and quantify the naturally occurring volatile chemicals that plants emit in response to plant and human BW pathogens.
  - Characterize transcriptional responses of plants to plants and human pathogens.
  - Continue development and evaluation of antibody replacement or enhancement techniques.
  - Continue development and evaluation of novel reporting/transduction techniques.
  - Characterize performance of hierarchical biochip sensors.
  - Expand library of signatures for bio-agents in mass spectrometry identification.
  - Optimize time-of-flight (TOF) mass spectrometer detection of aerosol live agents against clutter.
  - Continue time-of-flight mass spectrometer counter-proliferation related work.
  - Develop conceptual designs and critical technologies for novel warning systems, such as networked surveillance systems.
  - Develop Triangulation ID for Genetic Evaluation of Biological Risks (TIGER) gold standard biosensor to support environmental evaluations and system performance model validation.
  - Complete initial optimization of TIGER probe set for bacterial and viral threat.
  - Initiate statistical characterization of clutter for TIGER probe sets.
  - Explore BW background spectral signatures and initiate standoff sensor study to exploit agent unique signatures.
  - Develop front end sampling modules for cell and tissue based biosensors.
  - Demonstrate utility of cell and tissue based biosensors in operationally relevant scenarios.
  - Demonstrate the utility of social insects as BW agent collectors.
  - Evaluate rapid throughput methods for spore formers mortality due to decontamination.

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- Bio/Chem Defensive Systems. ($24.000 Million)
  - Continue fate and transport modeling around buildings for use in design and optimization of building-protection systems.
  - Continue development of building-appropriate decontamination techniques.
  - Evaluate novel approaches to combined filtration/neutralization.
  - Complete preliminary prototypes of enabling filtration, neutralization, and decontamination technologies for evaluation at full-scale.
  - Modify and instrument test facilities for evaluating building-protection systems.
  - Install preliminary protection components and prototypes into test facility.
  - Begin preliminary systems-level evaluation of protection strategies.
  - Initiate development of critical technologies for novel protection systems, such as portal barriers. Evaluate technologies suited to mail/package screening.

- Center for Water Security. ($1.000 Million)
  - Identify unique water purification techniques tailored to provide safe, potable water to population centers.
  - Resolve fundamental technical issues associated with large-scale purification techniques.

- Asymmetrical Products for BWD. ($3.000 Million)
  - Continue to explore use of cytokines as biological warfare therapeutics.

- Desalination Research. ($2.600 Million)
  - Continue to evaluate non-traditional approaches to desalination.

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(U) **FY 2003 Plans:**

- Anti-Virals/Immunizations. ($12.000 Million)
  - Down-select successful animal model system(s) and validate utility in the regulatory process for newly developed anti-viral agents against validated threat list agents.
  - Test initial viral targets identified by modeling viral RNA-protein interactions.
  - Demonstrate efficacy and validate (in-vivo) candidate antiviral therapeutic developed by combinatorial chemistry for viral infections emanating from validated threats.
  - Test candidate virally-derived cytokine inhibitor as a therapeutic for hemorrhagic fever viruses or other threat agents.
  - Evaluate (in-vivo) prototype multi-agent (two or more antigens) edible/mucosal vaccine.
  - Implement protocols to enable validated therapeutic products to transition to appropriate Service partner.
  - Implement strategies for Investigational New Drug (IND) and New Drug Application (NDA) enabling studies.
  - Develop in-vitro model system to evaluate potential of vaccine candidates.

- Anti-Bacterials/Anti-Toxins. ($12.000 Million)
  - Evaluate strategies for new therapeutics based on critical targets of host damage by pathogen (e.g., by development and use of animal models with engineered resistance, gene expression profiles).
  - Evaluate utility of animal models innately resistant to infection for identifying new therapeutic targets and host resistance factors.
  - Down-select successful animal model system(s) and validate utility in the regulatory process for newly developed anti-bacterial agents against validated threat list agents.
  - Demonstrate efficacy of high-throughput screening technologies in evaluating bacterial infections.
  - Develop strategies for new therapeutics based on host-pathogen signaling pathways and/or controlling pathogen gene expression.
  - Implement protocols to enable validated therapeutic products to transition to appropriate Service partner.
  - Implement strategies for Investigational New Drug (IND) and New Drug Application (NDA) enabling studies.
  - Develop treatment for late stage BW infections.

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- Multi-Purpose. ($15.000 Million)
  - Down-select successful animal model system(s) and validate utility in the regulatory process for newly developed therapeutic agents against validated threat list targets.
  - Demonstrate broadly applicable technologies to enhance cellular therapeutics and virulence modulation.
  - Evaluate (in-vivo) and validate monomeric and dimeric DNA and RNA binding molecules as novel countermeasures against multiple pathogens.
  - Identify and develop additional targets for subcellular pathogen imaging.
  - Implement protocols to enable validated therapeutic products to transition to appropriate Service partner.
  - Implement strategies for Investigational New Drug (IND) enabling studies.
  - Demonstrate novel approach in engineering metabolic responses to threat agents.
  - Develop methods for providing super normal protection from BW induced shock.
  - Engineer biological system with altered metabolic rate that demonstrates increased longevity and stability.
  - Optimize application of tissue engineering to DoD needs, including directed healing, tissue sculpting, and device development for two-dimensional and three-dimensional structures.
  - ID mutated genes that create BW resistance in mouse ethyl-nitroso-urea (ENU) models as potential targets for developing novel protective agents.
  - Develop bioreactive scaffolding for controlled release of differentiation factors in 3-dimensional tissue precursors.
  - Combine printing, scaffolding and differentiation to demonstrate in vitro organ constructs for immune system.

- External Protection. ($7.500 Million)
  - Demonstrate an air purification system suitable for both personal warfighter protection and collective protection for a group of soldiers.
  - Implement protocols to enable demonstrated protective products to transition to appropriate Service partners.

- Advanced Diagnostics. ($13.500 Million)
  - Demonstrate strategies for rapidly generating new probe panels for relevant sample types.
  - Demonstrate, in model systems, lead candidate strategies for rapid detection based on bodily responses or other biomarkers for early indication of infection or exposure.

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- Demonstrate multiplexed pathogen detection in microliter samples.
- Demonstrate new methods for rapid sequencing DNA.

• Sensors. ($25.000 Million)
  - Develop genomics-based tools to engineer plant and other organism responses to pathogens and chemicals in ways that are observable at a distance.
  - Integrate and test molecular replacement components into sensor systems.
  - Develop networked biosensors and algorithms for their integration to reduce false alarms.
  - Optimize biochip sensor and software analysis.
  - Complete optimization of Triangulation ID for Genetic Evaluation of Biological Risks (TIGER) probe set for full threat spectrum against clutter.
  - Complete TIGER biosensor performance modeling and prototpe preliminary design (PDR).
  - Demonstrate cell and tissue sensors in air and water quality applications.
  - Evaluate metrics of performance for social insect BW agent collector systems in the field.
  - Begin exploring the possibility that microbe specific chemical agents can tag microbial aerosols and make them observable at a distance via spectrometry.
  - Continue development of new engineering tools for designing and enhancing biological regulatory circuits.

• Bio/Chem Defensive Systems. ($32.000 Million)
  - Complete development of building-appropriate filtration, neutralization, combined filtration/neutralization, and decontamination techniques, and produce prototypes for full-scale testing.
  - Evaluate prototype performance against live agents in appropriate testing facilities.
  - Based on FY02 experimentation, design and implement full-scale protection systems optimized for a subset of threats. Carry out full-scale testing of system performance.
  - Collect data in full-scale test facilities for validation of transport models.
  - Develop software models of component and system behavior.
  - Initiate integration of software-based planning tool to model threat and mitigation effectiveness for building protection.

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- Select military site for full-scale demonstration of building protection, and begin site characterization including chemical/biological background sampling.
- Perform threat assessment for demonstration site.
- Continue technology development and develop the design and infrastructure requirements for novel protection systems. Conduct feasibility experiments for mail/package screening.

• BW Surveillance Techniques. ($ 9.000 Million)
  - Conduct trade studies of various potential detection architectures in selected urbanized areas; estimate system performance.
  - Initiate technology development to optimize components for this application.
  - Initiate development of analytic methods to geo-locate source based on detector output, meteorology, etc.
  - Initiate extensive background characterization experiments.

• Stand-Off BWD Sensors. ($ 7.000 Million)
  - Conduct controlled measurements of aerosol signature (fluorescence lifetime, Raman scattering, laser induced breakdown spectroscopy, etc.).
  - Develop predictive models for use in evaluating stand-off sensor concepts.
  - Develop prototypes of advanced techniques such as Surface Enhanced Raman Spectroscopy and UV Resonant Enhanced Raman Spectroscopy.

(U) **Program Change Summary:** (***In Millions***)	**FY 2001**	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	166.769	140.080	140.000
Current Budget	146.216	146.680	133.000

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(U) **Change Summary Explanation:**

FY 2001 Decrease reflects the transfer of the Bio & Chem Terrorism Response Training Program to 0602384BP, the SBIR reprogramming and minor program realignments.

FY 2002 Increase reflects congressional adds for Asymmetrical Protocols for Biological Defense, the Center for Water Security and Hydrate Fractionation Desalination Technology.

FY 2003 Decrease reflects completion of initial development and transition of several anti-viral, multipurpose, and anti-bacterial/anti-toxin pharmaceuticals into pre-approved investigation studies to be conducted by the services, offset by additional sensor and surveillance program efforts.

(U) **Other Program Funding Summary Cost:**

	FY 2001	FY 2002	FY 2003
Title IX, BWD Post-Exposure Therapeutics	0.000	30.000	0.000
Defense Emergency Response Fund (DERF)	0.000	0.000	(30.000)

Title IX funds were added by Congress for the Biological Warfare Defense (BWD) post-exposure therapeutics program. This effort will take six BW therapeutics far enough into clinical trials to accelerate availability in case of military necessity. In FY 2003, $30 million is requested from the DERF to complete this effort.

(U) **Schedule Profile:**

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	210.790	164.056	180.952	188.667	192.180	194.836	200.361	Continuing	Continuing
Naval Warfare Technology TT-03	4.965	23.389	28.952	33.736	23.777	19.884	0.000	0.000	N/A
Advanced Land Systems Technology TT-04	14.293	23.448	24.000	53.636	73.305	84.016	103.701	Continuing	Continuing
Advanced Tactical Technology TT-06	28.439	61.468	69.000	53.636	57.455	61.283	67.070	Continuing	Continuing
Aeronautics Technology TT-07	27.432	23.635	37.000	22.845	27.737	29.653	29.590	Continuing	Continuing
Advanced Logistics Technology TT-10	26.791	22.529	22.000	24.814	9.906	0.000	0.000	0.000	N/A
Joint Logistics ACTDs TT-11	9.570	9.587	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Unmanned Systems TT-12	99.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

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

(U) This program element is budgeted in the Applied Research Budget Activity because it supports the advancement of concepts and technologies to enhance the next generation of tactical systems. The Tactical Technology program element funds a number of projects in the areas of Naval Warfare, Advanced Land Systems, Aeronautics, and Logistics technologies. FY 2001 included congressionally added funding for Unmanned Systems initiatives (Project TT-12).

(U) The Naval Warfare Technology project is focusing on advanced enabling technologies for a broad range of naval requirements. The Friction Drag Reduction program will develop friction drag reduction technologies for surface ships and submersibles. The Hypersonics Flight

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Demonstration program will develop and demonstrate advanced technologies for hypersonic flight. This project also included funding for the Center of Excellence for Research in Ocean Sciences.

(U) The Advanced Land Systems Technology project is developing technologies for enhancing the U.S. military's effectiveness and survivability in operations ranging from force-on-force conflict to military Operations-Other-Than-War. The Alternatives to Antipersonnel Landmines program will explore technologies to obviate the need for mines. The Close-In Sensing program will emphasize new approaches to detect traditionally low signal-to-signal noise or concealed targets. The Guided Projectiles program focuses on highly maneuverable projectiles, launch systems and fire control. The Training Superiority program will create revolutionary new training techniques. Networking Extreme Environments will address integration of ultra wide band communications and sensor systems.

(U) The Advanced Tactical Technology project is exploring the application of compact and solid state lasers; high performance computational algorithms to enhance performance of radars, sensors, communications, and electronic warfare and target recognition and tracking systems; precision optics components for critical DoD applications; aerospace electronic warfare systems; high speed aerospace vehicle and enabling technology; and new tactical systems for enhanced air vehicle survivability, advanced airbreathing weapons, enabling technologies for advanced space systems and emerging payload delivery concepts.

(U) The Aeronautics Technology project explores technologies to reduce costs associated with advanced aeronautical systems and provide revolutionary new capabilities for current and projected military mission requirements. This project funds development of micro adaptive flow control technologies; small-scale propulsion system concepts; innovative vertical take-off and landing concepts; long endurance unmanned air vehicle concepts; and advances for tilt-rotor aircraft.

(U) The Advanced Logistics Technology project investigates and demonstrates technologies that will make a fundamental difference in transportation and logistics. The program will define, develop and demonstrate fundamental enabling technologies that will permit forces and sustainment materiel to be deployed, tracked, refurbished, sustained and redeployed more effectively and efficiently. The project will also develop and demonstrate advanced military-grade measures for security, robustness and scalability to enable the wide-scale application of large-scale agent technology to U.S. military logistics and command and control domains operating in high-tempo conventional and information warfare environments.

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(U) The Joint Logistics project, composed of two Advanced Concept Technology Demonstrations (ACTD), will develop and migrate interoperable web-based joint logistics decision support tools (JDST) to the Service logistics communities.

(U) The Unmanned Systems project pursued the development of unmanned advanced capability aircraft and ground combat vehicles consistent with Public Laws 106-259 and 106-398. Systems developed under this project included the Air Force and Naval Unmanned Combat Air Vehicles (UCAV) and Army Future Combat Systems (FCS).

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

	FY 2001	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	215.896	173.885	153.348
Current Budget	210.790	164.056	180.952

(U) **Change Summary Explanation:**

FY 2001	Decrease reflects the SBIR reprogramming and minor program repricings.
FY 2002	Decrease reflects congressional program reduction partially offset by the CEROS Add.
FY 2003	Increase reflects increased Agency emphasis on weaponry (high power lasers) and hypersonics.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-03				
COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Naval Warfare Technology TT-03	4.965	23.389	28.952	33.736	23.777	19.884	0.000	0.000	N/A

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

(U) The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. Enabling technologies include concepts for expanding the envelope of operational naval capabilities.

(U) The Friction Drag Reduction program will further develop friction drag reduction technologies investigated under PE 0601101E, Project MS-01, for surface ships and submersibles that can be practically implemented in the operational environment. The goal is the development of radical skin friction drag reduction sustained over time periods that are operationally relevant. The primary focus of this program is on two methods known to reduce friction drag: injection of polymers or microbubbles into the flow boundary layer. The program will address, by means of computation and small-scale laboratory experiments, the practical barriers to the implementation of polymer additives and microbubbles. Other drag reduction techniques that are discovered by these investigations will also be explored.

(U) The Hypersonics Flight Demonstration program (HyFly) will develop and demonstrate advanced technologies for hypersonic flight. Flight-testing will be initiated as early in the program as possible and progress from relatively simple and low-risk tests through the demonstration of an increasingly more difficult set of objectives. The ultimate goals of the program are to demonstrate a vehicle range of 600 nautical miles with a block speed of 4,400 feet per sec, maximum sustainable cruise speed in excess of Mach 6, and the ability to deploy a simulated or surrogate submunition. Technical challenges include the scramjet propulsion system, lightweight, high-temperature materials for both aerodynamic and propulsion structures, and guidance and control in the hypersonic flight regime. Recently demonstrated performance in ground testing of the dual combustion ram-jet engine coupled with advances in high temperature, light weight aerospace materials are enabling technologies for this program. The program will pursue a dual approach. The core program will focus on development and demonstration of capabilities requisite for and operational weapon. A separate effort will be performed in parallel to demonstrate advanced propulsion technologies and develop low-cost test techniques. DARPA is negotiating with the Navy to establish a joint program to pursue areas of the hypersonics program that would be relevant to maritime applications.

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(U) The Center of Excellence for Research in Ocean Sciences (CEROS) supports the Department of Defense by encouraging leading edge research and development in ocean sciences, exploiting exceptional Hawaiian ocean research facilities, involving highly specialized small businesses with recognized expertise in ocean related research, and providing access to the ocean sciences expertise of the University of Hawaii. Major research areas of interest have included shallow water surveillance technologies, ocean environmental preservation, new ocean platform and ship concepts, ocean measurement instrumentation, and unique properties of the deep ocean environment. Recent transitions of CEROS sponsored research into military and civilian applications indicate the success that DARPA has achieved in maturing these kinds of maritime technologies. DARPA and the Department of the Navy are currently in the process of investigating the possibility of transferring the management of the CEROS project to the Department of the Navy.

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

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

- Center of Excellence for Research in Ocean Sciences (CEROS). ($4.965 Million)
  - Selected projects for funding, both new efforts and follow-on development to projects selected in previous years.
  - Contracted selected projects and monitored progress of ocean related technologies of high interest to the DoD.
  - Transitioned appropriate products to military use.

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

- Friction Drag Reduction. ($5.600 Million)
  - Develop methodology for scaling drag reduction results previously demonstrated in concept evaluations to larger scale models appropriate for predicting the drag reduction in operationally relevant systems.
  - Validate initial modeling efforts through small-scale laboratory experiments.

- Center of Excellence for Research in Ocean Sciences (CEROS). ($4.700 Million)
  - Select projects for funding, both new efforts and follow-on development to projects selected in previous years.
  - Contract selected projects and monitor progress of ocean related technologies of high interest to the DoD.
  - Transition appropriate products to military use.

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- Hypersonics Flight Demonstration (HyFly). ($13.089 Million)
  - Perform preliminary and detailed design efforts and supporting materials-structural demos.
  - Conduct freejet aero-propulsion testing of the heavyweight vehicle configuration.
  - Perform ground test verification (static firing) of government furnished equipment supersonic low altitude target boosters.
  - Conduct captive carry, drop, boost performance and boost separation flight tests.
  - Conduct sled test of simulated submunition deployment.
  - Perform advanced combustion systems proof of concept testing in gun-launched test range.

(U) <u>FY 2003 Plans:</u>

- Advanced Naval Warfare Technology Concepts. ($1.952 Million)
  - Perform feasibility studies of emerging advanced technology concpets, including propulsion systems, active protection and survivability, enhanced maneuverability and hybrid electric power.

- Hypersonics Flight Demonstration (HyFly). ($27.000 Million)
  - Perform vehicle subsystems verification testing.
  - Conduct flightweight vehicle freejet performance and durability testing.
  - Conduct flightweight vehicle environmental testing.
  - Conduct initial, low flight Mach (~Mach 4.0) flight testing.
  - Conduct ballistic and free-flight subscale testing of advanced engine technologies.

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

- Not Applicable.

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

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-04				
COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Land Systems Technology TT-04	14.293	23.448	24.000	53.636	73.305	84.016	103.701	Continuing	Continuing

(U) Mission Description:

(U) This project is developing technologies for enhancing the U.S. military effectiveness and survivability in operations ranging from force-on-force conflict to military Operations-Other-Than-War (OOTW). This emphasis is on developing affordable technologies that will enhance the military's effectiveness while decreasing the exposure of U.S. or allied forces to enemy fire. This project consists of the following main efforts: Antipersonnel Landmines Alternatives; Close-In Sensing; Guided Projectiles, Networking Extreme Environments (NetEx); and Training Superiority.

(U) The Antipersonnel Landmine Alternative (APLA) program is developing technologies that provide our warfighter with enhanced capabilities that obviate the need for antipersonnel landmines (APLs). Technologies under investigation include self-healing minefields that achieve protection of antitank mines from both dismounted and mounted breaches without the use of APLs, and tags with minimally-guided, air-guided or ground-guided munitions to detect, locate and rapidly engage dismounted infantry permitting the compression of critical timelines and distance constraints that limit the effectiveness of conventional indirect and direct fires.

(U) The Close-In Sensing program will develop technologies and platforms to complement our national remote sensing assets. The close-in sensors will exploit various phenomenologies to make robust detection, classification, and identification of time-critical targets, hardened, hidden and highly protected targets and characterization of the local radio frequency (RF) environment. The technologies developed will emphasize new hardware and approaches to detect traditionally low signal-to-noise or concealed targets without placing people in harm's way and will emphasize infiltration and exfiltration technologies.

(U) The Guided Projectiles program will develop and demonstrate highly maneuverable gun-launched projectiles, launch system and fire control for point defense against highly maneuverable anti-ship cruise missiles, ground-to-air and ground-to-ground threats. The supersonic interceptors provide high rate, multiple engagement defense of critical tactical or strategic assets, including naval surface ships, airborne ISR platforms, and fixed radar/C3 sites. Supersonic flight control for aggressively maneuvering medium caliber projectiles will be developed and integrated into advanced projectile designs to achieve lateral accelerations far exceeding those achieved by “course-correcting” projectiles.

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(U) The Networking Extreme Environments (NetEx) program seeks to develop and integrate technologies that will enable, from the perspective of unattended sensors: (1) a thorough understanding of the effect of Ultra Wide Band (UWB) system operation on other spectrum users, and UWB system and channel properties; (2) improve the link margin of UWB hardware by 20dB and reduce the size and power consumption of the devices by more than an order of magnitude; (3) modify emerging ad-hoc routing and multiple access protocols to utilize the unique capabilities of UWB systems; and (4) develop a series of stressing demonstrations that will require integration of the UWB communications and sensors systems into an interoperating net to support military operations in harsh urban terrain. NetEx is an outgrowth of sensor reachback and connectivity research conducted under the Close-In Sensing program.

(U) The Training Superiority program will create new approaches to provide the Land Warrior and other warfare areas with increased technical and physical competence as a result of revolutionary new training techniques developed in this program. Passive teaching approaches, including web-based training, will not succeed in instilling the skills and knowledge needed in the new land battlefield, where there are expected to be higher demands on fewer soldiers, including the need to control and interact with highly technical unmanned systems. These new training approaches will include elements of human-tutor interactions and the emotional involvement of computer games coupled with the fidelity and feedback of Combat Training Center learning.

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

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

- Antipersonnel Landmine Alternatives. ($10.522 Million)
  - Conducted initial field experiments of self-healing minefield system.
  - Demonstrated autonomous location of individual mines and minefield mapping.
  - Evaluated tag communication range.

- Close-In Sensing. ($3.771 Million)
  - Investigated potentially promising radio frequency phenomenology collection techniques.
  - Investigated extremely lightweight, low cost active array technologies.
  - Explored multiple mission platform concepts.

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(U) **FY 2002 Plans:**

- Antipersonnel Landmine Alternatives. ($9.281 Million)
  - Integrate final self-healing minefield system concept.
  - Build and field test 50 mine prototypes.
  - Evaluate collective behaviors for breaching in simple minefields.

- Close-In Sensing. ($8.371 Million)
  - Continue trade off studies in advanced technologies for use in data infiltration and exfiltration.
  - Continue development of active array technologies.
  - Explore multi-sensor architectures and waveforms.
  - Initiate novel radio frequency exploitation concepts.
  - Investigate novel platform propulsion and drag reduction concepts.
  - Develop a test methodology to obtain a thorough understanding of how UWB systems interact with other spectrum users.
  - Design a flexible hardware UWB transmitter emulator.
  - Design a software UWB channel simulator.

- Guided Projectiles. ($5.796 Million)
  - Develop, model and validate supersonic flight control technologies.
  - Initiate system-level concepts and error budgets.
  - Conduct preliminary development and evaluation of key subsystem technologies.

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(U) **FY 2003 Plans:**

- Close-In Sensing. ($3.545 Million)
  - Complete active array component proof-of-concept.
  - Laboratory demonstration of novel data infiltration/exfiltration approaches.
  - Evaluate platform design to meet special mission needs.

- Guided Projectiles. ($6.455 Million)
  - Select one or more guidance and control system components and integrate them on projectiles of various sizes.
  - Perform initial flight demonstrations and target acquisition demonstrations.
  - Use virtual prototypes and simulations to determine the increase in effectiveness over “dumb” bullets; evaluate the logistic cost savings.
  - Fabricate and test critical subsystems for projectile maneuvering, guidance and data transmission.
  - Conduct detailed design and feasibility tests of key fire control, lethality, flight control and launch components.

- Antipersonnel Landmine Alternatives. ($2.000 Million)
  - Evaluate warhead and control electronics constraints for reduction of mine size.
  - Transition self-healing minefield concept to Services.
  - Develop initial design of RF tag; test macroscopic tag analog for initial demonstration of detectability.
  - Initial design of mortar mounted RF seeker and mortar control system.
  - Investigate potential mobility alternatives for a “tick” like munition attached to a host.
  - Evaluate potential microlethality approaches to be carried on the “tick” like munition.

- Networking Extreme Environments. ($6.000 Million)
  - Conduct Ultra Wide Band (UWB) interference testing.
  - Verify software simulator results with actual test data.
  - Issue UWB interference testing report.

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- Training Superiority. ($6.000 Million)
  - Define subject domains amenable to application of new training approaches.
  - Begin development of prototype training systems with reach-back to subject matter experts.
  - Establish approaches for modeling a student's knowledge and mental state that can be used to modify training approaches in real time.

(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 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Tactical Technology TT-06	28.439	61.468	69.000	53.636	57.455	61.283	67.070	Continuing	Continuing

(U) Mission Description:

(U) This project focuses on five broad technology areas: (a) compact, efficient, frequency-agile, diode-pumped, solid-state lasers for infrared countermeasures, laser radar, holographic laser sensors, and high-power laser applications; (b) high performance computational algorithms for signal processing, target recognition and tracking, electromagnetic propagation, and processing of advanced materials and microelectronics; (c) precision optics components for critical DoD applications; (d) aerospace electronic warfare systems (e.g., coherent spoofers, decoys, jammers); and (e) very high speed aerospace vehicle and enabling technology. Additionally, this project will develop new tactical systems for enhanced air vehicle survivability, advanced airbreathing weapons, enabling technologies for advanced space systems, and emerging payload delivery concepts.

(U) The Laser program will develop compact diode-pumped, solid-state lasers (ten fold improvement in efficiency) with at least tens of watts average power output and wavelength tuneability in the mid-infrared spectral regions to provide laser sources for infrared countermeasures against heat-seeking missiles for rotary wing/fixed wing aircraft and sea-borne platforms. Additionally, it will develop ultra broadband and very short pulse solid-state laser technology and ultra high power short pulse lasers. These programs will develop and demonstrate single mode fiber lasers with output powers of nearly one kilowatt from a single aperture. Tens of kilowatts output power and capability to scale to greater than hundreds of kilowatts output power and beyond will be demonstrated through coherent combination of the output power from multiple fiber lasers. High power fiber lasers will provide a quantum leap in defense capabilities by simplifying the logistic train and providing a deep magazine, limited only by electronic power, in a compact footprint. The advent of high power, reliable diodes with tunable ultra-short pulse widths and scaleable irradiance levels represents a technological advance of great potential utility to the DoD. The successful demonstration of a compact, efficient, and powerful laser diode could lead to incredible advances in communications, ultra-short pulse spectroscopy, micro-machining, LIDAR and directed energy applications with performance benefits with respect to its size, efficiency, and damage potential. These programs will also explore a combination of microelectromechanical systems (MEMS) based electro-optic spatial light modulators in combination with very short pulse solid state lasers to provide powerful new capabilities for secure communication up-links (multi-gigabits per second), aberration free three-dimensional imaging and targeting at very long ranges (greater than 1,000 kilometers). Lastly, innovative design concepts and system integration of MEMS-based spatial light modulators (SLMs), that provide a quantum leap in wavefront control, photonics and high speed electronics, will be explored for an affordable and high value communications, image sensing and targeting systems for use well into the 21st century.

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(U) The Mission Specific Processing (MSP) program, previously funded from PE 0602301E, Project ST-19, High Performance and Global Scale Systems, extends Adaptive Computing Systems (ACS) technologies to support the design of highly optimized embedded processors that are required in the most severely constrained DoD applications. ACS developed new approaches to the design of computer hardware that incorporated dynamic configuration capabilities. The technology developed by the MSP program will facilitate high performance processing in future space based and miniature aero systems (unmanned air vehicles and missiles) that require extremely high processing throughput while consuming the minimum possible volume, weight and power. The focus is on compressing the design time for such full custom designs to match that of standard cell systems, while providing a ten fold gain in performance.

(U) The High Performance Algorithm Development and Advanced Mathematics for Microstructural Process Control programs identify, develop and demonstrate new mathematical paradigms enabling maximum performance at minimum cost in a variety of DoD systems applications. They will look for opportunities to aggressively leverage the power of mathematical representations in order to effectively exploit the power of large-scale computational resources as they apply to specific problems of interest. The products are typically advanced algorithms and design methodologies. DARPA is pursuing the development of well-conditioned fast algorithms and strategies for the exploitation of high-dimensional data (i.e., data with a high number of degrees of freedom) in order to deal with a variety of complex military problems including virtual integrated prototyping of advanced material and device processing, digital representation and analysis of terrain and other geospatial data, efficient high fidelity scattering computations of radar scattering for predictive design and exploitation of radar cross sections, and efficient automatic mapping and optimization of signal processing kernels onto advanced DoD computational hardware architectures.

(U) The Integrated Sensing and Processing (ISP) program will open a new paradigm for application of mathematics to the design and operation of DoD sensor/exploitation systems and networks of such systems by developing and applying novel optimization methodologies for integrating sensing, processing, and information exploitation functionality in DoD sensor systems. This program will create tools enabling the design and global optimization of advanced sensor system architectures comprising fully interdependent networks of functional elements, each of which can fill the roles and functions of several distinct subsystems in current generation sensor systems. Payoffs will include improved performance with reduced complexity hardware and software in a wide variety of systems, including agile adaptive arrays for missile seekers, unmanned air vehicles, and spaceborne sensors; novel waveforms, adaptive waveform design and processing for object identification in dispersive and turbulent media; and novel approaches to multiplexed hyperspectral chemical/biochemical sensing systems.

(U) The Responsive Access, Small Cargo, Affordable Launch (RASCAL) program will develop and demonstrate the capability to launch small (less than 110 pounds) satellites and commodity payloads into low Earth orbit on demand and for a total launch cost of $10,000 per pound or

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less. This capability will enable cost effective use of on-orbit replacement and re-supply. This capability will also provide a means for rapid launch of orbital assets for changing national security needs. While the payload cost goal is commensurate with current large payload launch systems, it is more than a factor of five less than current capabilities for dedicated launch of payloads of this small size. This program will utilize reusable aircraft technology for the first stage and will take advantage of low-cost hybrid advanced rocket fuel technologies for the expendable upper stages. With recent advances in design tools and simulations this program will prudently reduce design margins and trade-off system reliability to maximize cost effectiveness. This program will also leverage advancements in autonomous range safety; first-stage guidance; and predictive vehicle health diagnosis, management and reporting to lower the recurring costs of space launch. FY 2003 and out funding for this program will be continued under PE 0603285E, Project ASP-02.

(U) The Water Rocket program will support research and development of a robust concept for space power and propulsion supported by water as a replenishable propellant and fuel. Water is an inexpensive and easily handled propellant. The program will develop and demonstrate thrusters that use water or its constituents, hydrogen and oxygen. High power thrusters will be developed for rapid maneuvering and high specific impulse thrusters will be developed for greater economy in use of the water propellant. A regenerative fuel cell system, enabled by emerging new technologies, will be developed and demonstrated. The regenerative fuel cell will serve two purposes: 1) it will convert the water to hydrogen and oxygen for use in thrusters, and 2) it will generate electricity while converting some of the hydrogen and oxygen back to water, thereby replacing the heavy batteries routinely used in satellites to supply electric power during nighttime. As a result of this program, future spacecraft will be more easily refueled for extensive maneuvering and changes of orbit to accomplish advanced missions.

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

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

- Compact Lasers for Coherent Communication, Imaging and Targeting. ($7.602 Million)
  - Developed preliminary system application concepts and preliminary design of spatial light modulators and integrated electronics. Developed preliminary breadboard system design with high-speed electronics integration.
  - Investigated very high power, short pulse lasers using plasma based pulse compression.

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- High Performance Algorithm Development. ($10.791 Million)
  - Demonstrated feasibility and portability of optimized portable application library generation approaches for a complete signal-processing algorithm.
  - Developed and tested algorithms for variable precision filters for adaptive signal processing.
  - Developed a tool set implementing algorithmic, memory and compilation models applied to a multipole test problem.
  - Developed algorithms for predicting and optimizing antenna radiation patterns and scattering, both off of and through, inhomogeneous materials and deep cavities.
  - Developed computationally efficient geometric compression and registration algorithms for topography/imagery databases.

- Advanced Mathematics for Microstructural Process Control. ($5.661 Million)
  - Validated reduced order model and algorithms for sensing and control of thin film vapor deposition processes.
  - Demonstrated advanced and/or accelerated molecular dynamics simulation techniques for the growth of multilayer materials.

- Advanced Tactical Technology Concepts. ($4.385 Million)
  - Performed feasibility evaluation studies of emerging advanced tactical technology concepts, including enhanced air vehicle survivability, innovative engines and propulsion techniques, payload delivery methods, and enabling technologies for advanced space systems.

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

- Compact Lasers for Coherent Communication, Imaging and Targeting. ($7.669 Million)
  - Develop 32x32 unit cell with scalable designs for spatial light modulator with integrated electronics.
  - Develop breadboard system with application specific hologram processor, receiver and short pulse amplifier.
  - Demonstrate greater than one-kilometer operation for static platform and target.

- High Power Lasers. ($10.263 Million)
  - Develop large mode-field area fiber designs and perform fabrications techniques.
  - Develop multiple designs for coherent combining of greater than 100 fiber lasers.

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- Model and evaluate concepts for ultra-short pulse widths and high irradiance.
- Demonstrate divergence angles of ~0.1°.
- Demonstrate tunable pulse widths from continuous wave to 10 nsec.
- Develop very high power, short pulse lasers using plasma based pulse compression.
- Investigate high power lasers with liquid gain medium.

• Mission Specific Processing (MSP). ($9.691 Million)
  - Conduct simulation and benchmarking of initial custom design techniques.
  - Verify ten fold improvement in giga operations per second watts per square centimeter operations per second for key Digital Signal Processor functions.
  - Develop detailed system architecture of wideband adaptive radar/electronic intelligence /seeker receiver.
  - Begin development of a wideband adaptive radar receiver based on custom cell libraries and module generators.
  - Select the target semi-custom, full scale chips for development.

• High Performance Algorithm Development/Virtual Electromagnetic Testrange. ($11.000 Million)
  - Demonstrate validated, high fidelity, efficient electromagnetic scattering prediction at frequencies up to X-band for cruise missile sized objects with simple boundary conditions (i.e., perfect electrical conductor and impedence boundary condition).
  - Demonstrate tool kit software for optimized design for thin film vapor deposition processes including real-time process control.
  - Demonstrate prototype tensor product language compilers for efficient automatic generation of digital filterbank algorithms.
  - Initiate design of digital representations for map and terrain imagery that will support highly efficient storage, query, and registration of geographical information from disparate sources.
  - Demonstrate localized representations for high-altitude gravity data with the precision of current representations with ten percent of current storage requirements.

• Integrated Sensing and Processing. ($6.000 Million)
  - Develop and demonstrate feature extraction and three-dimensional imaging capability in passive interferometric sensors.
  - Demonstrate feasibility of designs for quadrature thinning of two-dimensional conformal arrays, which exhibit the same or better beam patterns than conventional arrays and yet use only one-third of the transmit/receive modules.

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- Rapid Access, Small Cargo, Affordable Launch (RASCAL). ($12.000 Million)
  - Demonstrate aircraft propulsion adaptation to first-stage mission requirements.
  - Initiate Phase I: Conduct feasibility studies and concept definitions.
  - Perform reusable launch vehicle mass injection pre-compressor cooled risk reduction testing.
  - Design expandable rocket vehicle (ERV) avionics head stage.
  - Conduct ERV low cost feasibility studies/manufacturing demonstrations.
  - Establish system level design and feasibility of performance and cost goals.

- Water Rocket. ($4.845 Million)
  - Perform critical technology demonstrations and analysis of the system design for the regenerative fuel cell and other developmental components, including thrusters.

(U) **<u>FY 2003 Plans:</u>**

- Compact Lasers for Coherent Communication, Imaging and Targeting. ($10.000 Million)
  - Develop and demonstrate scalable designs for 1024x1024 spatial light modulator with integrated electronics.
  - Develop prototype system with high-speed parallel electronics.
  - Demonstrate horizontal slantpath communication links and aberration-free coherent imaging with ranges up to 10 kilometers.

- High Power Lasers. ($18.000 Million)
  - Demonstrate greater than 100-watt output power from large mode-field area fibers and coupling high brightness laser diode pumps.
  - Down select two designs of coherent combining of fiber lasers for one-kilowatt output power.
  - Model and design advantages of the ultra-short pulse regime for DoD applications.
  - Optimize intra-cavity grating design (geometry, placement, length, resolving power).
  - Demonstrate pulse widths of as short as ~ 0.1 psec using Thz gain pumping or pulse compression techniques.
  - Demonstrate 100 times power amplification of laser diode system as compared to state-of-the-art Fabry-Perot laser diodes (~ 100 kW/cm @10 psec).
  - Demonstrate very high power short pulse lasers using plasma pulse compression.

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– Develop high power lasers with liquid gain medium.

- Mission Specific Processing (MSP). ($12.000 Million)
  - Complete development of a wideband adaptive receiver system.
  - Demonstrate a ten-fold performance improvement in custom radar signal processing chips.
  - Begin integration of chips into a functional testbed.
  - Develop a test and demonstration plan for a fully functional adaptive radar processor.
  - Kernel library of key Digital Signal Processing functions and supporting tool augmentations complete.
  - Complete development of adaptive processor for seeker-receiver.
  - Complete design of innovative application specific integrated circuit (ASIC) architecture for Electronic Intelligence processor.
  - Transition MSP kernel library to ASIC fabrication vendors.
  - Conduct first pass evaluation of semi-custom, full scale chips.

- High Performance Algorithm Development/Virtual Electromagnetic Testrange. ($12.000 Million)
  - Demonstrate efficient, accurate predictive algorithms for electromagnetic scattering from inhomogeneous and anisotropic materials.
  - Demonstrate efficient scattering codes capable of accurate computation of Radar Cross Section for cruise-missile-sized vehicles with realistic material boundary conditions and full complexity components.
  - Demonstrate high fidelity computational electromagnetic modeling capability for multisensor apertures and arrays.
  - Demonstrate localized harmonic series representations of gravitational and other geospatial/navigational data that provide substantial accuracy and computational efficiency improvement over current schemes.
  - Determine tractable Bio Regulatory Network component subnetworks, manipulation techniques, measurement methodology, and data reduction approaches for cell-based simulation of analog circuits and control loops.
  - Determine feasibility of direct recognition of phonemes in analog to digitals for speech systems.
  - Determine optimal scheduling strategies for interleaving communication, electronic warfare and sensing on common multifunctional RF systems.
  - Develop reduced-order models and algorithms for sensing and control of biochemical materials growth processes.
  - Develop representations for low altitude gravity data with enhanced precision to support next-generation strike requirements and using ten percent of currently required storage.

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- Integrated Sensing and Processing. ($9.000 Million)
  - Develop and demonstrate spatio-spectral feature extraction and four-dimensional (three spatial, one spectral) reconstructions in passive interferometric sensors.
  - Demonstrate robust beamforming and adaptive array algorithms for quadrature-thinned two-dimensional conformal arrays exhibiting same or better cancellation of interference than conventional arrays with only one-third of the transmit/receive modules and with at least ten times the reduction in computational costs.
  - Demonstrate feasibility of contrast invariant geometry-based fusion of infrared video frames with digital terrain elevation data and feature data for applications to cruise missile mission planning.
  - Develop real-time waveform design and scheduling strategies for ambiguity reduction and clutter mitigation in pulse diversity radar systems.

- Coherent Combination of Solid State Lasers. ($4.000 Million)
  - Demonstrate use of spatial light modulator for coherent combination of many solid-state lasers.
  - Demonstrate use of higher order mode fiber laser (J=1).
  - Investigate coherent combining of J=1 fiber laser.

- Water Rocket. ($4.000 Million)
  - Complete detailed design and fabrication of brassboard and demonstration of the developmental components.

(U) Other Program Funding Summary Cost: *(In Millions)*

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-07				
COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Aeronautics Technology TT-07	27.432	23.635	37.000	22.845	27.737	29.653	29.590	Continuing	Continuing

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

(U) Aeronautics Technology efforts will address high payoff opportunities to dramatically reduce costs associated with advanced aeronautical systems and/or provide revolutionary new system capabilities for satisfying current and projected military mission requirements.

(U) Micro Adaptive Flow Control (MAFC) technologies enable control of large-scale aerodynamic flows using small-scale actuators. MAFC technologies combine adaptive control strategies, with advanced actuator concepts like micro-scale synthetic jets, MEMS-based microactuators, pulsed-blowing and smart structures to delay or prevent fluid flow separation. MAFC technologies will be explored for applications such as adaptive lift-on-demand for agile missiles and uninhabited tactical aircraft, lightweight gas turbine engines, and low-drag, non-intrusive methods to aerodynamically steer projectiles for extended range and precision. Advanced flow control concepts will be explored in the context of system level performance benefits and cost assessments. MAFC technology evaluations will be made under system-relevant flow conditions, and the most promising approaches will be selected for component- or system-level demonstration.

(U) Concepts for a new, small-scale class of propulsion systems will be developed in the size range from 0.5 cm to 5.0 cm in diameter, with thrust levels from 10.0g to 10.0 kg. They will enable future development of a new generation of very small weapons and military platforms including micro air vehicles, unmanned combat air vehicles, missiles and space launch vehicles. Radical new capabilities to be explored range from shirt-button-sized micro gas turbine and micro rocket engines to 5 cm scale gas turbine and pulse detonation engines. Engines may be explored at larger scale to prove feasibility. Examples of new mission capabilities may include delivery of very small (200 g) satellites to low earth orbit, extended range small-scale precision munitions, and lightweight, long endurance miniature reconnaissance vehicles. These small-scale munitions would complement emerging unmanned vehicle systems and greatly increase mission capabilities by simultaneously increasing loadout, range and precision.

(U) The Army, Navy and Marine Corps have a need for affordable, survivable, vertical take-off and landing (VTOL) air vehicles to support dispersed units in littoral and urban areas. The Advanced Air Vehicles (AAV) program explores innovative VTOL technologies and concepts with the potential for significant performance improvements that would satisfy stressing mission needs. One such concept is the advanced Canard Rotor/Wing (CRW) aircraft, that offers the potential for a high speed rapid response capability from a VTOL unmanned air vehicle with significant range and stealth improvements as compared to other VTOL concepts. Design and fabrication of this scaled vehicle concept will validate the command and control, stability and control system and aerodynamic performance required for vertical take-off, landing and hover via a rotating center wing that stops and locks in place for efficient high speed cruise.

(U) DARPA is continuing its investment in innovative, long endurance unmanned air vehicle (UAV) technology. The military application of such vehicles is the provision of reliable, tactically controlled intelligence, surveillance and reconnaissance (ISR) and communications equivalent to low earth orbit satellites. To achieve endurance on the order of two weeks, at operationally significant altitudes (60,000+ ft), with 250+ lb payloads it is necessary to develop airframes with very high strength and low structural weight. It is also necessary to develop high efficiency propulsion systems with sufficient peak power to provide station keeping in periodic high winds. Recent advances in high strength, all composite airframes, hydrogen fuel cell technology and high strength, composite, hydrogen dewars suggest that such a vehicle design is realizable.

(U) There is an increasing need for air lift capability to support quick response operations. To address this, the Unmanned Tilt-Rotor (UTR) program will exploit a new and revolutionary advance in tilt rotor aircraft, using the patented Optimum Speed Rotor (OSR) technology, demonstrated in the A160 Hummingbird UAV helicopter program. Scaling studies indicate that a very large tilt-rotor aircraft employing large diameter variable rpm OSR props/rotors for high efficiency hover and flight would achieve high transit speed (greater than 350 kts) and extremely long ranges. This technology will give rise to a VTOL cargo lifter capable of deploying directly from CONUS to combat and also have the capability for intra-theater transport of maneuver brigades. DARPA has determined that a rapid and cost-effective means to demonstrate the critical technologies in this vehicle is with a subscale UTR aircraft. The program will develop this advanced concept with a 8,500 lb UTR vehicle to optimize and demonstrate the OSR tilt-rotor technology.

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

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

- Micro Adaptive Flow Control (MAFC). ($15.757 Million)
  - Initiated fully implemented MAFC technology development and validation tests for scale model of V-22 lift enhancement, large scale wing model synthetic jet lift control, and delayed retreating blade stall.
  - Continued demonstration of high-speed compressor stage with aspiration flow control to give pressure rise of 3.4 across the stage.
  - Completed demonstration of biomorphic flapping flight.

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- Initiated the development of closed-loop MAFC technologies toward feasibility demonstrations.
- Initiated fully implemented MAFC technology development and validation tests for scale model of quad tilt rotor lift enhancement and drag reduction.
- Completed design of a supersonic inlet for mesoflap testing.

• Small Scale Propulsion Systems (SSPS). ($8.036 Million)
- Completed detailed design for propulsion systems.
- Completed critical subsystem fabrication and testing.
- Began fabrication of full propulsion systems.

• Advanced Air Vehicles: Canard Rotor/Wing (CRW). ($1.794 Million)
- Continued demonstrator fabrication.
- Conducted hardware in the loop and ground testing.

• Advanced Aeronautic Concepts. ($1.845 Million)
- Continued technology assessments and feasibility testing of advanced aeronautic concepts, including coordinated unmanned multi-ship complex aerobatic flying, single aircraft composed of multiple air vehicles, and application of natural flight mechanics to robotic systems.

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

• Micro Adaptive Flow Control (MAFC). ($9.373 Million)
- Assess actuator and control system performance, control authority, bandwidth and power requirements.
- Complete MAFC feasibility demonstrations for selected military applications, including scale model of V-22 lift enhancement, high speed inlet mesoflaps, large scale wing model synthetic jet lift control and delayed retreating blade stall.
- Initiate studies to integrate MAFC technologies into full-scale engine and aircraft systems. Initiate demonstration plan, including flight and field tests of integrated MAFC systems.

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- Small Scale Propulsion Systems (SSPS). ($7.365 Million)
  - Complete initial fabrication and testing of propulsion systems.

- Advanced Air Vehicles: Canard Rotor/Wing (CRW). ($2.047 Million)
  - Complete ground testing and initiate demonstrator flight tests.

- Long Endurance Hydrogen Powered Unmanned Air Vehicles. ($4.850 Million)
  - Conduct design trades and critical item demonstrations on structural and propulsion concepts.
  - Prepare preliminary design of 14 day, 250+ lb payload, 60,000 ft cruise UAV.

(U) **FY 2003 Plans:**

- Micro Adaptive Flow Control (MAFC). ($8.540 Million)
  - Continue closed-loop MAFC actuator and controller development.
  - Continue application of closed-loop MAFC under full-scale system conditions for hydrodynamic drag reduction, 40-mm grenade flight control, integrated inlet and compressor flow control, stator vane flow control and short take-off and vertical landing exhaust acoustic control.
  - Continue flight and field tests of integrated MAFC systems including V-22 lift enhancement, large-scale wing model synthetic jet lift control, and Quad Tilt Rotor lift enhancement and drag reduction.

- Small Scale Propulsion Systems (SSPS). ($7.200 Million)
  - Complete final fabrication and testing of propulsion systems.

- Advanced Air Vehicles: Canard Rotor/Wing (CRW). ($1.760 Million)
  - Complete demonstrator flight tests and produce final report.

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- Long Endurance Hydrogen Powered Unmanned Air Vehicle. ($12.000 Million)
  - Continue testing of critical items and subsystems related to structure, propulsion, flight control and payload.
  - Complete conceptual design of aircraft.

- Unmanned Tilt Rotor (UTR). ($7.500 Million)
  - Initiate preliminary design with focus on prop rotor, wing, tail and power train subsystems.
  - Perform risk reduction experiments and concept development analysis and simulation.

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

- Not Applicable.

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

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-10				
COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Logistics Technology TT-10	26.791	22.529	22.000	24.814	9.906	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) The overarching objective of the Advanced Logistics Technology project is to revolutionize the way the DoD plans, executes, monitors, and dynamically replans logistics support across the entire spectrum of operational environments from day-to-day routine peacetime operations, disaster relief, non-combatant evacuation, peacekeeping, peacemaking, and minor and major contingencies. The project consists of two major programs, the Advanced Logistics Program (ALP) that developed the core functional technologies and the UltraLog Program that will make the logistics information system inherently survivable even in the most hostile environments. Technology focus includes enhancing the robustness, stability and security of the core data and information processing, thus creating a resilient system that can protect and adapt itself under harsh, dynamic conditions.

(U) The Advanced Logistics Program (ALP) investigated and demonstrated technologies that will make a fundamental difference in transportation and logistics. The program defined, developed and demonstrated enabling technologies that will permit forces and sustainment material to be deployed, tracked, refurbished, sustained, and redeployed more effectively and efficiently than ever before. Currently, this is accomplished using isolated, independent, and sometimes incompatible systems, processes and data. Therefore, the very rapid replanning and redirection necessary to support missions involving simultaneous local and major regional conflicts is extremely labor intensive, inefficient, and time consuming. ALP leveraged information technologies to address these shortcomings. ALP focused on the following three areas: 1) development of applications providing a technology environment that allows warfighters to rapidly understand and assess the logistics and transportation implications of a crisis situation, to generate effective plans and courses of action, to monitor a plan's execution and to use that information to re-plan; 2) automated systems that enable significant efficiency improvements in transportation and logistics, such as improving access to data, monitoring the condition and status of shipments, personnel, inventories, logistics assets and the infrastructure, the creation of "plan sentinels" to serve as an early warning system for plan deviations, and improved theater distribution; and 3) development of a computer network infrastructure that allows distributed real-time visualization and interaction with all phases, elements and components of the military and commercial transportation infrastructure. The capabilities from these three areas were integrated and demonstrated in a prototype end-to-end system solution. This program came to completion in FY 2001.

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(U) The UltraLog program builds on the baseline security, robustness and scalability capabilities of the technology developed in the Advanced Logistics Program. UltraLog will develop and demonstrate advanced military grade measures for security, robustness, and scalability to enable the wide-scale application of large-scale agent technology to U.S. military logistics and command and control domains operating in high-tempo conventional and information warfare environments. Using the infrastructure developed by the ALP, UltraLog will pursue research breakthroughs in four main areas: (1) Security: Investigate information pedigree, white-noise generation, dynamic random routing, agent gateways, dynamic Public Key Infrastructure management, recovery reconstruction protection, dynamic communications and security measures, information rovers, correlation and isolation of compromised agents and other techniques to achieve a secure, trusted system even under directed information warfare attack; (2) Scalability: Investigate assured convergence, automatic dampeners, adaptive configuration, resource pooling/proxy, variable fidelity processes, sliding temporal horizons, reactive plan space management and other techniques to achieve a highly scalable and stable system even under very chaotic wartime environments; (3) Robustness: Investigate non-local persistence, fault tolerance and recovery, distributed consistency checking, partial state validation, dynamic communications-aware redundancy, dynamic adaptation, and other techniques to achieve a state of high survivability; and (4) Systems Integration and Development: Synergistically combine security, scalability and robustness techniques that will provide the highest level of capability while ensuring the overall functionality of the distributed logistics enterprise is preserved. Though many of the research efforts will be accomplished independently and in parallel, the real challenge will come in the integration synergy of the various techniques to produce the desired systemic effects.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Advanced Logistics Program (ALP). ($9.855 Million)
  - Developed the capability to automatically build a logistics plan in under one hour in support of a complex operational scenario, and to rapidly modify that plan to keep it accurate and relevant under changing circumstances.
  - Developed the capability to monitor resource information, availability, capacity and costs, and to view past, present and projected logistical situations.
  - Developed and demonstrated the ability of the ALP technology to operate on embedded devices in a mixed human/robotics environment.
  - Developed plans for conducting follow-on pilot tests.

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- UltraLog. ($16.936 Million)
  - Established the developmental and experimental environments, and the metrics and methods by which the initial experimentation will be evaluated.
  - Designed, developed and evaluated a variety of independent technologies for security, scalability and robustness that demonstrate the potential for extending and enhancing large-scale, distributed agent systems, with special attention to experimentally proving the feasibility of each technique based on a set of technical and functional requirements.
  - Performed systemic analysis of combinations and layering of developed technologies for overall effectiveness under varying experimental and environmental conditions.

(U) **FY 2002 Plans:**

- UltraLog. ($22.529 Million)
  - Develop, integrate and evaluate a synergistic collection of technologies providing dynamic information security and agent system survivability for sustained wartime logistics operations in a moderate information warfare environment.
  - Establish an instrumented and configurable test environment, which includes the ability to generate infrastructure and communications failures, chaotic requirement flows and selected security breaches.
  - Conduct review by external, independent evaluation teams of both the concept of operations and technical designs of the various system components to identify deficiencies and recommend improvements. Incorporate recommendations and mitigating approaches to ongoing development effort.

(U) **FY 2003 Plans:**

- UltraLog. ($22.000 Million)
  - Develop, integrate and evaluate a refined portfolio of technologies, integrated and layered, to provide effective security, scalability and robustness under a moderately chaotic wartime and information warfare environment.
  - Conduct further reviews by external, independent evaluation teams of both the concept of operations and technical designs of the various system components to identify deficiencies and recommend improvements. Incorporate recommendations and mitigating approaches to ongoing development effort.
  - Migrate maturing concepts and technologies to transition agencies and services using program developed agent technologies.

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- Use the test environment to demonstrate the survivability of the evaluation system under harsh, chaotic conditions similar to that of a major regional contingency supported by directed adversary information warfare attack.

(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 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Joint Logistics ACTDs TT-11	9.570	9.587	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) The Joint Logistics project is composed of two Advanced Concept Technology Demonstrations (ACTDs) that will develop and migrate interoperable web-based joint logistics decision support tools (JDSTs) to the Global Combat Support System . The initial Joint Logistics ACTD addressed Commander-in-Chief and Service requirements to develop JDST capability in the areas of Force Capability Assessment; Logistics Support Concept Generation and Evaluation; Distribution, Materiel Management, Maintenance Analysis; and Visualization. The follow-on ACTD, the Joint Theater Logistics ACTD (JTL ACTD) integrates and expands upon those and other capabilities to provide real-time management and analysis tools for logistics and operations interoperability. Tools developed in this second ACTD are called Joint Theater Logistics Decision Support Tools (JTLDSTs) to distinguish them from the tools developed in the original ACTD and to emphasize the focus upon forces associated with a Joint Task Force in a theater of operations. These tools will provide warfighters and logisticians with the abilities to: assess support force capabilities to perform mission tasks; develop and evaluate logistics operational support plans; monitor logistics operations; and, react to deviations from projected support. JTL tools will provide the fusion and correlation of plans and information for critical components of theater support, sustainment, and transportation systems providing effective management, analysis, and situational assessment to logistics commanders. JTL capabilities will include real-time interoperability between logistics and operations during all phases of planning and execution. Key data sources include Conventional Forces Database, Joint Total Asset Visibility, Joint Personnel Asset Visibility, the Global Transportation Network, the Joint Operational Planning and Execution System, and the Global Status of Readiness and Training System. This project concludes in FY 2002.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Joint Logistics ACTD. ($0.867 Million)
  - Transitioned Joint Decision Support Tools (JDST) capability into the Global Combat Support System.

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- Joint Theater Logistics (JTL) ACTD. ($8.703 Million)
  - Expanded JTLDST capability to integrate in-theater distribution support planning and infrastructure assessment, and to generate and compare alternative logistics support force concepts to support multiple operational courses of action. Tracked the execution of fuel sourcing and sustainment.
  - Incorporated and enhanced planned deviation detection technology and sentinels to display near real-time operational logistic activity for selected support items by location, provider and intended consumer.
  - Developed capability to rapidly assess the impact of operational changes upon the logistic support structure.
  - Developed a real-time in-theater management capability for critical fuel support that integrates execution of logistic support plans with logistics and operational data feeds.
  - Began to develop the capability to forecast the impact of deviations and alternative support concepts upon future operations.
  - Demonstrated multi-echelon collaboration of in-theater management capabilities in a joint warfighting exercise.
  - Began transition planning and discussions with GCSS personnel.

(U) **FY 2002 Plans:**

- Joint Theater Logistics (JTL) ACTD. ($9.587 Million)
  - Incorporate and enhance planned deviation detection technology and sentinels to compare planned resource requirements with near real-time operational logistic activity for selected support items by location, provider, and intended consumer.
  - Provide the warfighter with near real-time operations and logistic collaborative capabilities to support planning and execution.
  - Incorporate technologies that will track planned versus actual movements, and assess logistic readiness, selected weapons systems, and classes of supply.
  - Develop and demonstrate a watchboard capability to track and report operational and logistics status of current operations through a web-based framework.
  - Provide interactive models for requirements, availability and costs.
  - Integrate watchboard and common operational picture views to provide logistic overlays for the warfighter.
  - Demonstrate multi-echelon interoperability and in-theater management capabilities in a joint warfighting exercise.
  - Continue transition planning for incorporation of JTL ACTD products.

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(U) **FY 2003 Plans:**

- Not Applicable.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	255.026	344.554	440.500	550.126	594.165	612.074	631.442	Continuing	Continuing
Materials Processing Technology MPT-01	148.753	168.931	145.251	194.268	195.149	231.825	271.434	Continuing	Continuing
Microelectronic Device Technologies MPT-02	89.105	92.661	122.000	157.927	190.196	183.848	162.743	Continuing	Continuing
Cryogenic Electronics MPT-06	17.168	9.094	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Beyond Silicon MPT-08	0.000	73.868	94.999	84.700	66.173	43.194	39.453	Continuing	Continuing
Biologically Based Materials and Devices MPT-09	0.000	0.000	78.250	113.231	142.647	153.207	157.812	Continuing	Continuing

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

(U) This program element is budgeted in the Applied Research Budget Activity because its objective is to develop technologies related to those materials, electronics, and biological systems that make possible a wide range of new military capabilities.

(U) The Materials Processing Technology project concentrates on the development of novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and enable new missions for military platforms and systems as well as to increase human performance. Areas of concentration include exploitation of emerging processing approaches to tailor the properties and performance of structural materials and devices. This emphasis includes lightweight personnel protection, mesoscale machines for miniature devices, and ultra lightweight and amorphous materials. Approaches for materials risk reduction will also be explored. The project also focuses on smart materials, sensors and actuators, functional materials and devices,

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advanced magnetic materials for non-volatile, radiation hardened magnetic memories, and electroactive polymers for sensing and actuating. Other areas of concentration include new materials concepts for portable power, development of bio-interface materials and methods, energy harvesting concepts, and frequency agile materials based on ferrite and ferroelectric oxides. Electronics Textiles will develop new technologies and manufacturing techniques for economic manufacture of large-area, flexible conformable information systems. This project also includes a biological systems thrust. The unique characteristics of biologically derived functional materials and devices will be exploited through the understanding and control of the structure and chemistry of the interface between man-made and biotic materials. In addition, emulation and/or control of biological functionality (i.e., sensing and mobility) will be explored for enhanced DoD applications (sensor, robotic, etc.). Biologically Based Materials and Devices programs transfer to Project MPT-09 beginning in FY 2003.

(U) The Microelectronics Device Technologies project supports the continued advancement of microelectronic device technologies (digital, analog, photonic and micro-electromechanical) through the development of performance driven advanced capabilities, exceeding that available through commercial sources, in electronic, optoelectronic and MEMS devices, semiconductor device design and fabrication techniques, and new materials and material structures for device applications. A particular focus for this work is the exploitation of chip-scale heterogeneous integration technologies that permit the optimization of device and integrated module performance. Areas of emphasis include high-performance analog-to-digital converters, military optical processors, novel integrated optoelectronic devices and components, high temperature electronic devices, and high power electronics. Additionally, this project will focus on advanced microelectronics technologies such as digital radar receivers and acoustic-electronic components; optical signal processing of military RF waveforms; and high frequency/high power wide band gap semiconductor technologies. The project also initiated a significant effort to develop advanced materials and device technology beyond the classical scaling limits of silicon device technology. These efforts transferred to project MPT-08 in FY 2002.

(U) The Cryogenic Electronics project funds specific applications of thin-film electromagnetic materials in electronic devices and circuitry for military applications. Thin-film high temperature superconducting components packaged with cryogenic devices are being applied to radars, electronic warfare suites, and communications systems to enhance performance while reducing size and power requirements. Highly dependable and inexpensive cryocoolers (including thermoelectric coolers) are being developed for these applications, and expanded efforts will explore techniques to improve the performance of all solid-state thermoelectric coolers as well as the overall cryogenic performance in applications ranging from communications to computing.

(U) The Beyond Silicon project is investigating the feasibility, design, and development of powerful information technology devices and systems using approaches to electronic device designs that extend beyond traditional Complementary Metal Oxide Semiconductor (CMOS) scaling, including non-silicon based materials technologies, to achieve low cost, reliable, fast and secure computing, communication, and storage systems.

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This investigation is aimed at developing new capabilities; from promising directions in the design of information processing components using both inorganic and organic substrates, designs of components and systems leveraging quantum effects and chaos, and innovative approaches to computing designs incorporating these components for such applications as low cost seamless pervasive computing, ultra-fast computing, and sensing and actuation devices.

(U) The Biologically Based Materials and Devices Project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials and devices as well as the commensurate influence of materials, physics and chemistry on new approaches to biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials for enhancement of performance, the development of multifunctional transducers based on biological membranes, and the application of magnetic materials in biological applications.

(U) <u>Program Change Summary</u>: (*In Millions*)

	FY 2001	FY 2002	FY 2003
FY02 Amended President's Budget	261.883	358.254	298.875
Current Budget	255.026	344.554	440.500

(U) <u>Change Summary Explanation:</u>

FY 2001 Decrease reflects the SBIR reprogramming.

FY 2002 Decrease reflects congressional program reduction partially offset by several Congressional Adds in MPT-01 and MPT-02.

FY 2003 Increase reflects the continuation of the High Power Electronics/Wide Band Gap program and the initiation of Adaptive Focal Plane Arrays, Vertically Interconnected Sensor Arrays and Ultra-High Speed Digital Circuit Technology programs (MPT-02) and the new project, Biologically Based Materials and Devices (MPT-09).

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Materials Processing Technology MPT-01	148.753	168.931	145.251	194.268	195.149	231.825	271.434	Continuing	Continuing

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

(U) The major goal of this project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems.

(U) One important area of concentration is the exploitation of emerging processing approaches to tailor the properties and performance of structural materials and devices. Thrusts in this area include new concepts for lightweight personnel protection as well as ultra lightweight materials, amorphous and multi-functional materials for lowering the weight and increasing the performance of aircraft, ground vehicles, and spacecraft structures. Approaches are also being developed for reducing the risk of using new materials in defense acquisitions and maintaining them in the field. Techniques are being established for assessing damage evolution and predicting future performance of the structural materials in defense platforms/systems through physics-based models and advanced interrogation tools.

(U) The mesoscopic size range ("sugar cube to fist") offers significant advantages in devices for defense. Efforts include mesopumps for battlefield sensors and mesocoolers for the individual soldier and water lubricated, energetic mesoengines. Technology for the mask-less, direct-write of mesoscopic integrated conformal electronics will enable the three-dimensional integration of both active and passive components, significantly reducing the size, weight and cost of integrated electronics functions (circuits, batteries, antennae, etc.). Mesoscale materials technologies will also be employed in novel approaches for obtaining and purifying water in the field.

(U) Smart materials, sensors and actuators for the control of the aerodynamic and hydrodynamic behavior of military systems are being developed and demonstrated to increase performance and lower detectability of aircraft, helicopters, and submarines as well as to increase human performance. "Intrinsically smart" materials that provide self-diagnosis and/or self-repair will be developed as well. Machines are being developed that would increase soldiers physical capabilities augmenting speed, strength and endurance. Advanced materials, devices, and structural architectures are being investigated that would allow military platforms to morph or change shape, thus adapting optimally to mission requirements.

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(U) Another major thrust is the development of functional materials and devices. This includes advanced magnetic materials for high sensitivity, magnetic field sensors; non-volatile, radiation hardened magnetic memories with very high density, short access time, infinite cycleability and low power; novel materials and device structures for high frequency acoustic imaging; and electroactive polymers for sensing, actuating, and analog processing. Frequency-agile materials based on ferrite and ferroelectric oxides are being developed for tuned filters, oscillators, and antennas. New permanent magnetic materials with significantly higher magnetic strength and higher operating temperature for motors, generators, flywheels, bearings and actuators are also being explored. Unique fabrics that can change their porosity or display information will be investigated. Engineered materials (metamaterials) are being developed that provide improvements in electromagnetic behavior across the complete array of defense applications. Finally, new techniques will be developed for atomic level resolution probing of defect densities and composition profiles in semiconductors and other novel materials.

(U) The unique characteristics of biologically inspired and biologically derived materials and devices will be exploited through the understanding, control, and emulation of the structure and chemistry of the interface between man-made and biotic materials, and hybrid bioelectronics that electronically control biological organisms or use biological intelligence for smart materials. The direct utilization of biological systems for the production of unique, bioderived materials will be investigated. Structure and function emulated from biological systems will result in new biomimetic systems that capture unique locomotion and sensing schemes. The fundamental operating principles of biomolecular motors will be developed and exploited to design nano to macro scale devices having unparalleled energy efficiency. Bio-inspired optical components will allow the development of multifunctional optical systems with reduced complexity and weight. (Biologically based materials efforts will move to a new project, MPT-09 in FY 2003 to acknowledge the growing and pervasive influence of biological science on the development of new materials and devices.)

(U) New materials and concepts for increasing the availability of portable power to the soldier are being investigated, as are approaches for deriving power from the environment for soldiers and sensors. Novel approaches for direct energy conversion from thermal sources such as submarine nuclear reactors are also being investigated.

(U) The Electronics Textiles (e-Textiles) program will develop a revolutionary new integrated electronic and textile technology capability base and industry by leveraging the formerly independent electronic and textile industries. The underlying conceptual advance or enabling technology is the development and insertion of electronic mixed signal yarns and textiles into everyday fabrics and fabric-based infrastructures. As a result, textiles will have the revolutionary ability to sense, act, store, emit, and move while leveraging an existing low cost textile-manufacturing infrastructure. This new cabability will enable the integration of many formerly discrete physical devices/packages and functions into a

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compressible, homogeneous, intelligent textile system that will support rapid field deployment and adaptation plus provide a new set of revolutionary war fighting capabilities such as covert sensing, intelligent decoys, smart uniforms, and space sails and antennas.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Structural Materials and Devices. ($26.435 Million)
  – Demonstrated concepts for ultra-lightweight armor with 100 percent improvement over current materials and began full-scale testing.
  – Demonstrated the use of multifunctional materials to provide significant improvement in the capabilities of defense systems by providing additional functions (e.g., self-healing, thermal control, blast protection, power) to load bearing structures.
  – Continued the optimization of analytical, experimental and simulation technologies for determining the properties and processing of advanced polycrystalline, nanocrystalline and amorphous materials.
  – Selected specific material(s) of high value to a DoD system for demonstration of accelerated insertion concepts.

- Mesoscopic Structures and Devices. ($14.200 Million)
  – Demonstrated initial, one-dimensional mesoscopic gyroscope operation that has drift rates less than one degree per hour.
  – Demonstrated fully functional integrated mesoscopic coolers that exhibit a coefficient of performance greater than three.
  – Demonstrated that direct-write mesoscale active and passive components have functionality close to discrete surface mount components.
  – Demonstrated the ability to direct-write mesoscale passive components (resistors, capacitors) and antennas on conformal surfaces.
  – Explored energetic machines and devices that aid the soldier in urban terrain.

- Smart Materials and Actuators. ($25.800 Million)
  – Completed wind tunnel test verification of an active aircraft engine inlet enabling a 20 percent increase in aircraft mission radius compared to a conventional fixed geometry inlet design.
  – Completed water tunnel test of a subscale submarine propulsor with active control to reduce acoustic radiation levels.
  – Explored techniques that use the intrinsic response of a material to its operating environment to provide diagnosis of the performance life of the material.

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- Developed approaches for integrating actuators, power systems and control methods to affect lightweight, energy efficient actuators for enhancing the performance of soldiers.
- Investigated artificial materials and membranes that can be integrated into controllable variable porosity fabric.
- Demonstrated methods to fabricate multilayer actuators made from single crystals of relaxor piezoelectrics.
- Demonstrated the performance of single crystal piezoelectrics in an advanced Navy sonar transducer.

- Functional Materials and Devices. ($40.836 Million)
  - Demonstrated a prototype, very high effective density (greater than 16 Mbit), high speed (less than 10 nsec access time) magnetic memory circuit based on giant magneto-resistance (GMR) or spin-dependent tunneling utilizing very low power and low voltage (less than 2.5 volts).
  - Demonstrated a steerable, ferroelectric lens for phased array radar.
  - Demonstrated a conformal, frequency agile antenna that is 100 times cheaper than conventional technology.
  - Explored applications of metamaterials for advanced electromagnetic devices (e.g., antennas).
  - Demonstrated advantages of polymer-based actuators in specific Defense applications (e.g., robotics, sonar, BW sensors).
  - Demonstrated the use of electroactive polymers as thin-film spatial filters for quasi-real-time multispectral image analysis for enhancing target detectability.
  - Investigated various multi-chromal fabrics that can be integrated along with conventional fabrics and be used to display information to a soldier on the uniform.

- Bioinspired Materials and Devices. ($7.082 Million)
  - Identified candidates for advanced sensor systems that incorporate biologically inspired concepts including self-calibration, self-healing, variable temperature operation, functional responsiveness and mobility.
  - Constructed prototype microelectronic interfaces for control of biological systems.

- Advanced Energy Technologies. ($16.900 Million)
  - Demonstrated energy harvesting from the environment for unattended sensor and soldier applications.
  - Demonstrated high efficiency direct thermal to electric energy conversion operating on a liquid hydrocarbon fuel.
  - Developed specific approaches for small, chemical power generation that operates at near ambient temperatures.

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– Investigated novel ultra-high energy density power source concepts.

- Bio: Info: Physical Systems Interface. ($5.000 Million)
  – Created new families of catalysts and pathways for synthesizing compounds and materials biomimetically.
  – Explored new architectural components and assembling principles of biological systems; developed new artificial matrices and assembling processes.
  – Developed new materials and matrices for sensing, actuation and computation via biologically inspired routes to material synthesis.

- Materials in Sensors. ($9.500 Million)
  – Continued work in materials and processing, including investigation of novel polymer and inorganic sensor and sensor protection schemes based on electroactive polymer and carbon nanotubes.

- Strategic Material Manufacturing. ($3.000 Million)
  – Continued to develop new manufacturing approaches for cutting tools and other ceramics used for Defense applications.

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

- Structural Materials and Devices. ($32.500 Million)
  – Evaluate concept for ultra-lightweight armor materials in a system with 100 percent improvement over currently fielded systems; transition to Army.
  – Identify models and mathematical techniques for capturing the physics of failure and behavior prediction in materials suitable for providing information on the degree of in-situ damage accumulation.
  – Demonstrate solutions to critical technical issues for the accelerated insertion of materials, quantifying potential payoff (time and resources) of each. Begin the integration of these technologies into a methodology that will allow designers to cut the insertion time of new materials by over 50 percent.
  – Quantify the performance of multifunctional structures that combine structure with additional functions, significantly reducing the parasitic weight of the structure in defense systems. Specific functions to be demonstrated include: self-healing, power generation, and self-sensing.

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- Develop and verify models that predict bulk amorphous metal formation; describe the deformation behavior of structural amorphous metals. Use these models to produce bulk amorphous materials with superior properties as compared to crystalline materials, including increased fracture toughness and high strain rate behavior.
- Investigate novel, cost effective processing routes for structural materials of interest to Defense (e.g., Ti).

• Mesoscopic Structures and Devices. ($20.200 Million)
  - Demonstrate the ability to "dial-in" any passive component with at least five percent tolerances with direct-write electronics manufacturing tool.
  - Fabricate direct-write batteries on complex geometries.
  - Demonstrate two-dimensional patterning of two cell types with the associated microelectrode array using direct-write.
  - Fabricate high efficiency direct-write antennae on low-temperature substrates.
  - Investigate concepts for highly power-dense, portable mesoscale machines and devices that aid the soldier in urban terrain.
  - Evaluate concepts for obtaining water from non-traditional sources.
  - Model and evaluate concepts to desalt brackish water with low energy.

• Smart Materials and Actuators. ($29.992 Million)
  - Demonstrate the utility of smart materials and adaptive structures in military platforms.
  - Complete flight test of a rotorcraft with blades containing integral actuators and flaps for control of noise and vibration.
  - Develop concepts that exploit smart materials to create new high power actuators for a variety of military platforms.
  - Demonstrate energy efficient electronics for smart actuator systems.
  - Demonstrate integrated power and actuation systems that exploit energy dense fuels.
  - Develop models that describe the dynamic performance required from actuators to augment soldiers in a variety of mission scenarios.
  - Explore system architectures for enhancing soldier physical performance including lower extremities for locomotion augmentation and upper extremities for strength augmentation.

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- – Demonstrate pilot production technology for piezocrystals in quantities and at cost suitable for prototype devices.
- – Demonstrate, on laboratory scale, targeted Naval sonar device/system performance using piezocrystals.
- – Investigate advantages and enabling capabilities created by allowing shape change to occur in military platforms.

- Functional Materials and Devices. ($38.530 Million)
  - – Demonstrate rad hard embedded magnetic random access memory for insertion into space and missile platforms.
  - – Demonstrate prototype frequency and phase agile antennas and filters for transition to radar and communication systems.
  - – Demonstrate embedded magnetoresistive non-volatile radiation hard memory for reconfigurable processors.
  - – Investigate the electronic capabilities (sensors, transistors, etc.) of electronic polymers in Defense applications.
  - – Demonstrate use of electroactive polymers in color displays, including flat panel and real three-dimensional displays.
  - – Demonstrate exchange-biased ferromagnetism in a bulk material.
  - – Develop processing approaches for low-cost manufacturing of high-performance printed optics (e.g., gradient index lenses).
  - – Demonstrate/validate “left-handed” wave propagation at microwave frequencies.
  - – Demonstrate low-power, compact, acoustic imaging beamformer technology with a large number of channels (more than 1,024).
  - – Demonstrate 1.5 dimension acoustic imaging array technology with a large number of elements (more than 1,024).
  - – Develop mathematical methodology for predicting macroscopic material characteristics from unit cell properties.
  - – Explore new methods for imaging defect and composition profiles in novel materials.

- Bioinspired and Bioderived Materials and Devices. ($14.251 Million)
  - – Demonstrate new capabilities in functionalizing magnetic nanoparticles for integration with biological hosts.
  - – Evaluate alternative biological energy sources for driving biomolecular motors.
  - – Isolate, modify and integrate biomolecular motors with man-made materials as a first step in developing devices with unique energy conversion capabilities and potential DoD utility.
  - – Explore soft materials (e.g., actuators, adhesives) in biological systems for potential Defense applications.
  - – Define new materials for coordinated appendage function in land and air platforms that utilize biomimetic principles of locomotion and actuation.
  - – Demonstrate biomimetic sensory prototypes that collect electromagnetic, olfactory and visual inputs.
  - – Identify genes that are responsible for stable biomaterials from organisms that survive environmental extremes.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-01

   - Explore multifunctional materials from organisms that survive environmental extremes and define design principles for biomimetic materials development.
   - Develop reduced-order mathematical control techniques for biochemical materials growth process.
   - Identify biomaterials and processes that are associated with stress reduction and extended physical and medical performance on the battlefield.

- Advanced Energy Technologies. ($20.558 Million)
   - Fully integrate and demonstrate energy harvesting technologies with military applications.
   - Explore novel approaches for power generation based on sonoluminescence and related technologies.
   - Fabricate and test new direct methanol membrane electrode assemblies based on materials breakthroughs in membranes and catalysts.
   - Design a second-generation portable direct methanol fuel cell with 50 percent higher performance than the first generation.
   - Demonstrate direct electrochemical oxidation of hydrocarbon fuels at moderate temperatures in a single cell solid oxide fuel cell suitable for a hand-held system.
   - Develop concepts for hand-held hydrocarbon-fueled portable power sources in the 20-watt power range for advanced soldier systems.
   - Demonstrate high performance thermoelectric, thermionic or other direct thermal power generation and/or cooling devices for military and commercial applications.
   - Evaluate undersea energy sources for in-situ harvesting, processing, and use in undersea platforms and vehicles.

- Electronic Textiles. ($7.000 Million)
   - Initiate the design of novel fiber based active and passive components.
   - Weave, knit and/or braid components into test structures and develop electrical interconnection and physical mounting schemes.
   - Analyze performance characteristics of the components, structural and subsystem integrity including routing, buss structures and interconnection schemes to demonstrate the feasibility of incorporating the components into woven circuitry.
   - Evaluate requirements and implementation characteristics for large area applications comprised of novel materials and micro-systems.

- Advanced Materials, Frequency Tunable Materials. ($1.500 Million)
   - Investigate nano particles for the fabrication of frequency tunable materials and components.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-01

- Strategic Material Manufacturing. ($3.400 Million)
  - Continue development of new manufacturing approaches for cutting tools and other ceramics used for Defense applications.

- Detection and Destruction of CW-Nanotechnology. ($1.000 Million)
  - Develop technologies for detection and destruction of chemical weapons using nanostructured materials.

(U) <u>FY 2003 Plans:</u>

- Structural Materials and Devices. ($33.000 Million)
  - Validate, using existing designer data that the accelerated insertion methodology will cut the insertion time of a new material by over 50 percent. Initiate the application of the methodology to new materials that, if inserted, will significantly improve Defense systems.
  - Fabricate prototype systems that demonstrate the value of multifunctional materials to Defense applications.
  - Demonstrate the use of a multifunctional material as structure plus battery for a micro air vehicle.
  - Demonstrate fabrication (forming, joining, etc.) technologies that yield bulk amorphous metals suitable for Defense applications, especially those that require high fracture toughness, even at high strain rates.
  - Quantify the impact of using bulk amorphous materials in construction of land vehicles and naval vessels.
  - Integrate models and sensor data into a system for providing current state awareness and structural performance prediction for Defense systems.
  - Demonstrate the use of flight information to predict life and failure of critical structural components.
  - Demonstrate novel process routes to structural materials of interest to Defense, including bronze castings for Navy application.
  - Explore techniques for large volume, low cost synthesis and assembly of nanomaterials and nanotubes with controlled attributes; exploit assembly processes to develop hierarchical/topological arrangements and structures to attain unique and multiple properties.
  - Demonstrate the microfabrication technology for amorphous metal MEMS devices and fabricate structures for evaluation.

- Mesoscopic Structures and Devices. ($15.000 Million)
  - Demonstrate the ability to direct-write semiconductor solar cells on low-temperature substrates.
  - Demonstrate the ability to direct-write robust embedded sensor systems with the physical structure along with appropriate encapsulation.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-01

- Demonstrate the ability to direct-write transistors, filters, and other active circuitry components economically, conformally, on low temperature substrates (plastics, kapton, etc.), and over large (greater than 12" x 12") areas.
- Explore techniques for patterning and/or altering the electromagnetic and structural properties of large area surfaces.
- Fabricate, using direct-write approaches, a three-dimensional pattern of two cell types in three-dimensions to mimic endothelial cells and smooth muscle cells.
- Demonstrate mesoscale energetic devices that create mechanical energy efficiently from chemical fuel sources utilizing precision fluidic controls, enabled by smart materials and MEMS.
- Demonstrate active membrane control for improved water flux and quality.
- Mitigate biological fouling of desalting membranes.
- Proof of concept demonstrations for water from air; test and evaluate optimized humidity concentration.

• Smart Materials and Actuators. ($31.000 Million)
  - Develop novel fluidic and mechanical systems to transmit energy from driver smart materials.
  - Using experimentally verified models, simulate the use of compact hybrid actuators for applications to military platforms.
  - Demonstrate man-machine interfaces that generate command signals and actuation from human physiological response.
  - Demonstrate man-wearable, powered actuation systems suitable for integration with the soldier.
  - Demonstrate an integrated, powered system for augmenting the locomotion and strength of soldiers using precisely controlled actuators and haptic interfaces that will link powered actuation to a soldier's movements.
  - Demonstrate, on field scale, targeted Naval sonar device/system performance using piezocrystals.
  - Develop devices and design structures that allow for morphing of structural systems during missions.
  - Model the performance gains of morphing structures within the context of a variety of concepts of operations for military platforms.
  - Initiate materials development efforts that will provide controllable shape changing systems that will ultimately increase the performance of air and space vehicles.

• Functional Materials and Devices. ($30.251 Million)
  - Demonstrate bulk meta materials with exchange biased permanent magnets with energy product greater than 60 megagausoersteds at room temperature.
  - Demonstrate novel properties of "left-handed" materials (e.g., negative Doppler shift).

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-01

- Demonstrate meta material advantage in developing effective media with high permeability and low loss at microwave frequencies.
- Demonstrate the ability of an electroactive polymer to perform muscle-like sensing and actuation in Defense robotic applications.
- Demonstrate quantitative advantages of using the electronic capabilities (sensors, transistors, etc.) of electroactive polymers in Defense applications.
- Demonstrate performance of printed optics suitable for defense sensor applications (visible and/or infrared).
- Demonstrate rectification of microwave signal using metamaterial rectenna.
- Continue demonstration of low-power, compact, acoustic imaging beamformer technology with a large number of channels (more than 1,024).
- Continue demonstration of 1.5 acoustic imaging array technology with a large number of elements (more than 1,024).
- Demonstrate a novel technique for determining defect density and composition profiles of semiconductors and other novel materials.
- Explore the mechanisms of phonon engineering for enhancing transport properties in organics.

- Electronic Textiles. ($14.000 Million)
  - Develop and evaluate early prototypes of novel fiber based active and passive components.
  - Initiate yarn circuit analysis and textile circuit modeling efforts.
  - Perform yarn-to-yarn connectivity experiments.
  - Fabricate test samples of woven electronic circuits for characterization.
  - Demonstrate a discrete functional electronic textile for a selected DoD large area application.

- Advanced Energy Technologies. ($22.000 Million)
  - Demonstrate a portable direct methanol fuel cell system with 50 percent higher performance than the first generation.
  - Fabricate and test components for hand-held direct hydrocarbon energy conversion devices.
  - Demonstrate a 40-watt solid oxide fuel cell stack with internal reforming of hydrocarbon fuel.
  - Design and fabricate 20-watt hand-held direct hydrocarbon energy conversion devices for advanced soldier systems.
  - Develop extracting and processing technologies for undersea energy sources for stationary and mobile platforms.
  - Design a small, safe, nuclear driven compact power sources.
  - Demonstrate enabling direct thermal to electric conversion technologies with potential for high (better than 20 percent) conversion efficiencies and high (greater than 2 W/cm^2) power densities for DoD applications in electric drive and/or propulsion.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-01

- Develop power source and other concepts based on acoustically driven systems.
- Develop the technology base for small, safe, nuclear driven compact power sources.

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

- Not Applicable.

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

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Microelectronic Device Technologies MPT-02	89.105	92.661	122.000	157.927	190.196	183.848	162.743	Continuing	Continuing

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

(U) Advances in microelectronic device technologies, including digital, analog, photonic and microelectromechanical (MEMS) devices, continue to have significant impact in support of defense technologies for improved weapons effectiveness, improved intelligence capabilities and for enabling information superiority. The Microelectronics Device Technologies Project supports the continued advancement of these technologies through the development of performance driven advanced capabilities, exceeding that available through commercial sources, in electronic, optoelectronic and MEMS devices, semiconductor device design and fabrication techniques, and new materials and material structures for device applications. A particular focus for this work is the exploitation of chip-scale heterogeneous integration technologies that permit the optimization of device and integrated module performance.

(U) The Reconfigurable Aperture (RECAP) program provides revolutionary antenna technology for future military needs in high capacity communication and sensors. Technologies being advanced include: artificial magnetic conductors, RF MEMS switches, photonic band gap ground planes, high-density multi-layer interconnects, and fragmented antennas. These are being integrated into demonstrations that will show substantial new capabilities such as multi-beam arrays for communication and multi-band radar links that electronically reconfigure to provide hemispherical coverage. Applications such as the Future Combat System need such battlefield links. Wideband antenna technologies will allow simultaneous Electronic Support Measures (ESM) and radar functions from a single aperture. Finally, this technology will also allow the number of antennas on aircraft and ships to be reduced by a factor of 5 – 10.

(U) The Acoustic Micro-Sensors program goal is to demonstrate a miniature acoustic sensor system based on MEMS transducers and advanced non-linear signal processing techniques for three-dimensional detection, capture, and tracking of sound sources in noisy environments with optimum sensitivity.

(U) The Materials Integration on Silicon program will demonstrate technologies and applications of direct integration of advanced materials and devices, such as high-speed logic and RF transistors with semiconductor integrated circuits.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

(U) The Photonic Wavelength and Spatial Signal Processing (Photonic WASSP) program goal is to develop photonic device technologies that allow the dynamic manipulation of both the spectral and spatial attributes of light for sensing, image pre-processing, bio-chemical sensing and general spectral signature analysis.

(U) Included within this project are several initiatives that began in FY 2002 including the Analog Optical Signal Processing Program, TEAM, the Chip Scale Atomic Clock and two Wide Band Gap Semiconductor programs.

(U) Analog Optical Signal Processing (AOSP) will significantly enhance the performance of, and enable entirely new capabilities/architectures for, tactical and strategic RF systems by expanding the dynamic range-bandwith and time-bandwidth limits by a factor of 1,000 through the introduction of analog optical signal processing components into the system front ends.

(U) Technology for Efficient, Agile Mixed Signal Microsystems (TEAM) will enable fabrication of high performance mixed signal systems-on-chip (SoC) that will be the core of the embedded electronics in new platforms that are constrained by size and on-board power.

(U) The Chip Scale Atomic Clock will demonstrate a low-power chip scale atomic-resonance-based time-reference unit with stability better than one part per billion in one second. Application examples of this program will include the time reference unit used for GPS signal locking.

(U) High Frequency Wide Band Gap Semiconductor Electronics Technology will develop wide band gap semiconductor technology and demonstrate high performance, cost effective high power electronic devices that exploit the unique properties of wide band gap semiconductors. This program will develop low defect epitaxial films, high yield fabrication processes, and device structures for integrated electronic devices for emitting and detecting high power radio frequency/microwave radiation, and high power delivery and control.

(U) An initiative in High Power Wide Band Gap Semiconductor Electronics Technology will develop components and electronic integration technologies for high power, high frequency microsystem applications based on wide band gap semiconductors.

(U) Four new initiatives are budgeted in FY 2003 including the Ultra High-Speed Digital Circuit Technology program, a Phase II effort for Wide Band Gap Semiconductors, the Adaptive Focal Plane Array effort, and VISA – Vertically Interconnected Sensor Arrays.

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(U) The Ultra High Speed Digital Circuit Technology program will demonstrate the application of Indium Phosphide compound semiconductor materials for high speed circuit application to digital signal synthesizer and related signal processing applications.

(U) The Adaptive Focal Plane Arrays (FPA) program will develop and demonstrate infrared FPA that are electrically tunable, thus enabling real-time reconfiguration of the arrays for intelligent chip-scale sensing and imaging missions.

(U) The Vertically Interconnected Sensor Arrays (VISA) program will develop and demonstrate imaging readout technology, which will result in revolutionary improvement in the performance of Defense imaging systems. This will be accomplished through the development and implementation of novel three-dimensional imaging architectures, which emulate the visual process in living beings.

(U) The phenomenal progress in current electronics and computer chips will face the fundamental limits of silicon technology in the early 21st century, a barrier that must be overcome in order for progress to continue. The Beyond Silicon initiative explores alternatives to silicon based electronics in the areas of new electronic devices, new architectures to use them, new software to program the systems, and new methods to fabricate the chips. Approaches include nanotechnology, nanoelectronics, molecular electronics, spin-based electronics, quantum computing, new circuit designs, and other approaches to electronic device designs that extend beyond traditional Complementary Metal Oxide Semiconductor (CMOS) scaling to non-silicon based materials technologies. Given DoD emphasis in this area, the Beyond Silicon programs are funded in project, MPT-08, within this program element in FY 2002 and beyond.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Reconfigurable Aperture (RECAP). ($13.459 Million)
  - Demonstrated fabrication and reconfigurability of fragmented antennas for wideband communication.
  - Constructed antennas with zero shift phase ground planes, switchable elements and polyimide materials for low cost component fabrication.
  - Continued successful core technologies and initiated efforts for integrated system application demonstrations concentrating on battlefield communications through low profile communications, space/air/surface/submarine-based electronic intelligence (ELINT), signal intelligence (SIGINT) and multiband radar systems.
  - Initiated validation of the RENOIR modeling and simulation tool (developed under the RECAP program) with experimental data.
  - Demonstrated dual polarization wideband antenna technology.

- Acoustic Micro-Sensors. ($5.557 Million)
  - Demonstrated MEMs-based 3-D acoustic transducers and transducer arrays with superior sensitivity, signal-to-noise ratio and bandwidth that are current state-of-the-practice.

- HERETIC. ($7.650 Million)
  - Demonstrated devices on GaAs having better specific heat-removal capacity as the best commercial-off-the-shelf thermo-electric coolers.
  - Demonstrated micro-jets, micro-nozzles, or micro-thermionic emitters on Si having much better heat-removal capacity as the best convective air or liquid cooling systems.

- 3-D Microelectronics. ($1.986 Million)
  - Continued development of key technologies behind a packaging concept that uses a stacked multi-chip module approach to reduce interconnect length and increase physical connectivity between layers of electronics.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

- VLSI Photonics. ($7.565 Million)
  - Demonstrated a Synthetic Aperture Radar (SAR) processor using VLSI Photonics technologies; showcased reconfigurable cross-connect switching.
  - Demonstrated rapid parallel access to memory using optical interconnection.

- Materials Integration on Silicon. ($8.484 Million)
  - Continued integration of new material and processes into a single silicon substrate that will drive system performance.
  - Demonstrated logic circuits and power amplifiers on silicon substrates.

- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($10.780 Million)
  - Continued component development, integration, algorithms, architectures and sub-system functionality demonstrations.
  - Demonstrated emitters and detectors in the spectral band 350-500 nm.

- Beyond Silicon - Antimonide Based Compound Semiconductors (ABCS). ($7.852 Million)
  - Demonstrated non-silicon based transistors technologies based on low band gap materials capable of multi-gigahertz operation at bias voltages less than one volt.
  - Demonstrated nanostructured materials for quantum based electronic and optoelectronic device applications.
  - Demonstrated a three terminal resonant tunneling device operating at several hundred GHz.

- Beyond Silicon - Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD). ($3.765 Million)
  - Developed fast algorithms for non-linear analysis of mixed signal systems – analog and photonic devices.
  - Extended algorithm methods to non-linear problems.

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- Beyond Silicon - Polymorphous Computing Architecture (PCA). ($7.714 Million)
  - Identified and selected DoD reactive in-mission and multi-mission applications of interest along with complementary commercial applications to ensure commercial viability.
  - Developed PCA hardware abstraction models and stable architecture framework.
  - Identified multi-dimensional reactive computing, communication, memory, verification and optimization techniques, and candidate implementations.

- Beyond Silicon - Quantum Information Science and Technology (QuIST). ($14.293 Million)
  - Investigated techniques for building reliable scaleable quantum bits out of devices potentially subject to failures and decoherence, via efficient fault tolerant mechanisms.
  - Investigated new problem classes, beyond factorization and unsorted search, which are solvable with dramatic efficiency on a quantum computer.
  - Initiated theory and algorithm research for secure quantum communication.
  - Investigated techniques amenable for implementation in existing networks and fiber optic backbone.

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

- Acoustic Micro-Sensors. ($4.073 Million)
  - Integrate MEMs-based 3-D acoustic transducer array with read-out electronics.
  - Demonstrate acoustic microsystem for remote detection and tracking of voices or sound sources in noisy outdoor environments.

- Materials Integration on Silicon. ($6.456 Million)
  - Complete technology development and demonstrations.
  - Demonstrate heterogenous fabrication processes and technologies for integrating disparate semiconductor devices and materials.
  - Complete fabrication of composite microcircuits that demonstrate advanced capabilities through the incorporation of devices from multiple materials.
  - Evaluate feasibility of flexible, mobile, high-resolution display components for wireless communications.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($9.861 Million)
  - Develop micro-machined optical elements for spectral bands 300 to 500 nm and 3 to 15 microns.
  - Initiate integration of the passive elements into beam conditioners.

- Reconfigurable Aperture (RECAP). ($7.000 Million)
  - Integrate and assemble component technologies into single sub arrays, which replace multiple antenna systems.
  - Develop and demonstrate low cost fabrication processes to support technology transition.
  - Initiate demonstrations of applications in low band communications, ELINT/SIGINT and multiband radar.
  - Complete validation of RENOIR modeling and simulation software.

- Analog Optical Signal Processing (AOSP). ($7.212 Million)
  - Perform analysis of analog signal characteristics of military RF systems.
  - Create, model and simulate new photonic-based optical signal processing techniques of ultra-high bandwidth analog signals.
  - Evaluate anticipated system performance improvements due to novel signal processing algorithms and determine the resulting photonic component performance requirements.
  - Test signal processing techniques of analog signals.
  - Evaluate signal-processing algorithms.
  - Evaluate photonic component performance requirements.

- Technology for Efficient, Agile Mixed Signal Microsystems (TEAM). ($6.309 Million)
  - Develop and demonstrate nanoscale silicon-based structures and associated fabrication processes to achieve high-speed analog/RF functions.
  - Optimize device and process parameters for high speed mixed signal circuits.
  - Produce test devices for analog/RF parameter extraction.
  - Demonstrate Complementary Metal Oxide Semiconductor (CMOS) compatible fabrication processes that can yield integration levels greater than 10,000 nanoscale devices.
  - Initiate highly parallel densely interconnected architectures with micron-sized vias penetrating stacks of detectors, analog, mixed signal and digital circuits.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

- Chip Scale Atomic Clock. ($4.350 Million)
  - Demonstrate feasibility and theoretical limits of miniaturization of cesium clock.

- High Frequency Wide Band Gap Semiconductor Electronics Technology. ($24.000 Million)
  - Demonstrate uniform growth of epitaxial wide band gap semiconductor films on substrates.
  - Develop bulk and surface process technologies for reducing or mitigating crystallographic defects in wide band gap materials.
  - Develop coupled electro thermal and physical models for design of high power device structures.

- High Power Wide Band Gap Semiconductor Electronics Technology. ($13.000 Million)
  - Develop electro thermal models for analyzing high power, high frequency enclosures.
  - Develop thermal management technologies for high power, high temperature devices.
  - Identify military system requirements and platform heat-management constraints.
  - Evaluate maximum thermal load capacity at the integrated circuit level.
  - Demonstrate effective high temperature adhesives and high power interconnect techniques.
  - Develop high frequency, high temperature passive components for integration with high power devices.

- 3-D Microelectronics. ($1.400 Million)
  - Continue development of key technologies behind a packaging concept that uses a stacked MCM approach to reduce interconnect length and increase physical connectivity between layers of electronics.

- Center for Optoelectronics and Optical Communications. ($2.000 Million)
  - Initiate optoelectronic and optical communications development.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

- Center for Integrated Technologies. ($5.000 Million)
  - Initiate photonic technology integration.

- Boron Energy Cell. ($2.000 Million)
  - Develop the science and technology base for boron energy cells.

(U) <u>FY 2003 Plans</u>:

- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($10.561 Million)
  - Demonstrate integration with packaging module.
  - Demonstrate module in a testbed for bio-chemical sensing and spectral imaging.
  - Transition technology to DoD hypospectral/imaging programs and systems.

- Reconfigurable Aperture (RECAP). ($11.000 Million)
  - Use Renoir model to estimate impact of RECAP technologies on existing and future antenna systems.
  - Complete demonstrations.

- Analog Optical Signal Processing (AOSP). ($14.000 Million)
  - Design, fabricate and test individual photonic components capable of meeting RF signal processing requirements.
  - Determine the most promising approaches for development of integrated, chip-scale components using new materials and processing technologies.
  - Determine interface requirements.
  - Evaluate the suitability of the new components for use in prototype modules.
  - Down-select to the most promising approaches and begin prototype module assembly.
  - Construct testbeds capable of fully characterizing the photonic-based RF signal processing components.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

- Technology for Efficient, Agile Mixed Signal Microsystems (TEAM). ($12.000 Million)
  – Demonstrate operation of high performance mixed signal circuits based on nanoscale devices.
  – Demonstrate low noise interface and high isolation (up to 100 db) between high performance analog circuits and associated digital signal processing.
  – Fabricate mixed signal systems on chip with nano-scale transitors.

- Chip Scale Atomic Clock. ($12.000 Million)
  – Demonstrate subcomponent fabrication, including atomic chamber, excitation and detection function.
  – Demonstrate design and fabrication innovation for atomic-confinement cell.
  – Demonstrate design and fabrication innovation for GHz resonators suitable for phase locking or direct coupling with atomic confinement cell.

- Wide Band Gap Semiconductor Electronics Technology. ($30.000 Million)
  – Develop semi-insulating substrate for high frequency devices.
  – Demonstrate control and activation of extrinsic dopants.
  – Develop a high quality oxidation process for application to metal-oxide-semiconductor (MOS) structures and demonstrate high carrier mobility in MOS structures.
  – Design low loss integration platforms for high power, high frequency operation.
  – Design high power enclosures for microwave electronic assemblies.
  – Demonstrate large periphery high power devices suitable for microwave and mm-wave operation, and large area power switches devices.
  – Develop RF materials and device designs.
  – Demonstrate high temperature operation of integrated power switches.
  – Demonstrate process reproducibility and minimization of yield limiting factors.
  – Establish device characterization for very high power solid-state amplifiers and power control devices.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02

- Adaptive Focal Plane Arrays. ($11.000 Million)
  - Demonstrate next generation of imaging sensors providing multiple imaging functions on a single compact array suitable for the micro-systems planned for future combat platforms.
  - Focus on multi-band detectors with integral target discrimination and high operating temperature, matching or exceeding performance that is only available in large, more costly sensors.
  - Integrate heterogeneous detector materials to realize chip-scale hyper-spectral imaging.

- Vertically Interconnected Sensor Arrays (VISA). ($12.750 Million)
  - Implement highly parallel densely interconnected architectures with micron-sized vias penetrating stacks of detectors, analog, mixed signal and digital circuits.

- Ultra High Speed Circuit Technology. ($8.689 Million)
  - Initiate development of Indium Phosphide compound semiconductor materials for very high speed circuit applications.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-06

COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Cryogenic Electronics MPT-06	17.168	9.094	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) Thin-film electromagnetic materials have reached a stage of development where specific applications can be identified in electronic devices and circuitry for military systems. Films may be deposited and patterned to form electromagnetic components in ways that are similar to, and compatible with, the processes of conventional semiconductor manufacturing. Such electromagnetic components, as well as complementary metal oxide semiconductors (CMOS), work best at lower temperatures, so that cryogenic packaging generally will be required for optimum performance. Thin-film high temperature superconducting (HTS) components packaged with cryogenic devices are being applied to radars, electronic warfare suites, and communications systems to enhance performance by more than an order of magnitude while reducing size and power requirements. Particular demonstrations include detection and geolocation of targets of high interest based upon low-level characteristic emissions and communications receivers with greater immunity to interference. Highly dependable and inexpensive cryocoolers are also being developed for these applications. These latter development efforts include the exploration of techniques to improve the performance of solid-state thermoelectric materials and devices in applications ranging from communications to power generation.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Totally Agile Sensor Systems (TASS). ($17.168 Million)
  - Fabricated a cryogenic module, operating as a front-end pre-selector, to enhance the sensitivity of a receiver to detect low-level emitters in the presence of multiple interferors.
  - Designed a complete cryogenic receiver module, incorporating tunable HTS antenna/pre-selector and digital microelectronics (with HTS embedded passives), displaying unsurpassed sensitivity and interference rejection.

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(U) FY 2002 Plans:

- Totally Agile Sensor Systems (TASS). ($9.094 Million)
  - Incorporate agile front-end pre-selector modules on aircraft and ships, utilizing tunable high-Q HTS filters.
  - Demonstrate totally agile sensor systems with ten times SIGINT and COMINT capability.
  - Fabricate Thermoelectric modules that can be integrated with receiver front ends to provide cooling and/or thermal management as required for enhanced performance.
  - Transition capability for 30 percent tunability to RC-135 aircraft demonstration.
  - Adapt capability for tunability greater than 50 percent for demonstration in a receiver console, with features for sweep rate and filter reconfiguration.

(U) FY 2003 Plans:

- Not Applicable.

(U) Other Program Funding Summary Cost:

- Not Applicable

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY	R-1 ITEM NOMENCLATURE
RDT&E, Defense-wide BA2 Applied Research	Materials and Electronics Technology PE 0602712E, Project MPT-08

COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Beyond Silicon MPT-08	0.000	73.868	94.999	84.700	66.173	43.194	39.453	Continuing	Continuing

(U) Mission Description:

(U) The phenomenal progress in current electronics and computer chips will face the fundamental limits of silicon technology in the early 21st century, a barrier that must be overcome in order for progress to continue. The Beyond Silicon project explores alternatives to silicon based electronics in the areas of new electronic devices, new architectures to use them, new software to program the systems and new methods to fabricate the chips. Approaches include nanotechnology, nanoelectronics, molecular electronics, spin-based electronics, quantum computing, new circuit architectures optimizing these new devices, and new computer and electronic systems architectures.

(U) The Beyond Silicon project investigates the feasibility, design, and development of powerful information technology devices and systems using approaches to electronic device designs that extend beyond traditional Complementary Metal Oxide Semiconductor (CMOS) scaling, including non-silicon based materials technologies, to achieve low cost, reliable, fast and secure computing, communication, and storage systems. This investigation is aimed at developing new capabilities; from promising directions in the design of information processing components using both inorganic and organic substrates, designs of components and systems leveraging quantum effects and chaos, and innovative approaches to computing designs incorporating these components for such applications as low cost seamless pervasive computing, ultra-fast computing, and sensing and actuation devices. The programs within this project were initially budgeted in PE 0601101E, Project MS-01 and PE 0602712E, Project MPT-02 in FY 2001.

(U) The Quantum Information Science and Technology (QuIST) program will explore all facets of the research necessary to create a new technology based on quantum information science. Research in this area has the ultimate goal of demonstrating the potentially significant advantages of quantum mechanical effects in communication and computing. Technical challenges include loss of information due to quantum decoherence, limited communication distance due to signal attenuation, limited selection of algorithms and protocols, and scalability to large numbers of bits. Error correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Signal attenuation will be overcome by exploiting quantum repeaters. New algorithm techniques and complexity analysis will increase the selection of algorithms, as will a focus on signal processing. Scalable solid-state technologies will integrate thousands of qubits on a single device. Expected

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impacts include highly secure communications, algorithms for optimization in logistics and wargaming, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking.

(U) The Polymorphous Computing Architectures program is developing a revolutionary approach to the implementation of embedded computing systems to support reactive multi-mission, multi-sensor, and in-flight retargetable missions and reduce payload adaptation, optimization, and verification from years to days to minutes. Current DoD embedded computing systems can be characterized as static in nature, relying on hardware-driven, heterogeneous point-solutions that represent static architectures and software optimizations. The program breaks the current development approach of hardware first and software last by moving beyond conventional silicon to flexible polymorphous computing systems. The key efforts of this revolutionary step forward in embedded computing systems are: 1) define critical reactive computing requirements and critical micro-architectural features; 2) explore, develop and prototype reactive polymorphous computing concepts; 3) explore, develop and prototype multi-dimensional verification and validation techniques for dynamic reactive missions; and 4) provide early experimental testbeds and prototype polymorphous computing systems. The result will be an embedded computing processing capability that will be mission and technology invariant yet highly optimizable for each new mission instantiation, thus providing for tactical and strategic mission tempo opportunities as well as technical upgradability over the life of the computing system. Based on an average of four major upgrades over a 30 year period, significant saving of up to 45 percent in development and deployment costs may now be achieved over the life of a typical DoD embedded computing system.

(U) Included within this project is a program to develop low power high frequency electronics circuits and infrared (IR) sources based on the Antimonide family of compound semiconductors (ABCS). Specific IR source goals include operating above thermoelectric cooled temperatures and greater than 10 percent efficiency with continuous wave (cw) in the Mid-Wave Infrared (MWIR) and single mode cw operation in the Long-Wave Infrared (LWIR).

(U) The Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD) program will develop and demonstrate innovative approaches to Computer Aided Design (CAD) of Mixed Signal (Analog/Digital) and Mixed Electronic/Photonic systems. The goal is to enable the design and prototyping of ultra complex microsystems with a high degree of integration and complexity for both military and commercial applications.

(U) This project continues the molecular electronics (Moletronics) program initially funded in Basic Research (6.1) to demonstrate the integration of multiple molecules, nanotubes, nano-wires, etc., into scalable, functional devices that are interconnected to the outside world with the potential to provide low power, a wide range of operating temperatures and much greater device density. This research will also demonstrate the

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scalability of molecular scale electronics to circuits containing 10^{11} elements and for densities equivalent to $10^{11}/cm^2$ and show that hierarchical self-assembly processes can be employed to build molecular circuits.

(U) The Interconnected Nano-scale Electronics and Substrates (INES) program aims to interconnect and integrate massive numbers of nano-scale switching devices with conventional deeply-scaled microelectronics. This will enable high performance sensor signal and data processing with very low power dissipation. This program will develop the fabrication technology for creating, placing and interconnecting massive numbers of nanoscale switching devices with high performance interfaces to integrated microelectronic substrates.

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

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

- Beyond Silicon programs in this PE were initially funded under Project MPT-02. ($33.624 Million)
  - Quantum Information Science and Technology.
  - Polymorphous Computing Architectures.
  - Antimonide Based Compound Semiconductors.
  - Integrated Mixed Signal (A/D) and Electronic/Photonic Systems.

- Moletronics was initiated in PE 0601101E, Project MS-01. ($8.337 Million)

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

- Quantum Information Science and Technology (QuIST). ($23.827 Million)
  - Investigate alternative designs and devices for low overhead fault tolerant communication and computation including solid state, quantum bit (qubit) memory and reliable generation of entangled qubits.
  - Determine quantum architecture and design solutions for problems such as graph isomorphism, imaging and signal processing.
  - Investigate alternative protocols for secure quantum communication, quantum complexity and control.
  - Explore designs that can be potentially implemented in existing fiber plants and free space, to include high-energy coherent state mechanisms and polarization compensation.

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- Polymorphous Computing Architectures. ($12.058 Million)
  - Characterize and perform functional decomposition of pivotal reactive system algorithms and computing functions.
  - Develop a representative scalable benchmark suite.
  - Develop and evaluate initial polymorphous computing architecture concepts.
  - Develop multi-dimensional reactive computing optimization, verification techniques.
  - Initiate early prototyping of reactive concepts, software services.

- Antimonide Based Compound Semiconductors (ABCS). ($11.368 Million)
  - Substrate Technology. Accelerate recent breakthroughs in lateral epitaxial overgrowth and thin film delaminating and rebonding to develop a source for ABCS substrates with essentially any desired thermal and/or electronic property.
  - Electronics Integration. Raise levels through a series of demonstrations of analog, digital or mixed signal circuits with increasing device count which have beyond state-of-the-art performance in terms of frequency of operation and low power consumption.
  - Demonstrate robust semi-insulating ABCS substrate material.

- Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD). ($11.239 Million)
  - Develop Model Order Reduction methods (for analog and photonic devices) to enable the creation of behavioral models.
  - Develop and demonstrate top-down design capabilities for analog, mixed signal and mixed electronic/photonic systems that match the efficiency currently achieved with digital designs.
  - Develop fast solvers for analog and photonic devices; perform non-linear model order reduction, develop extraction tools, synthesis and layout capabilities for mixed signal and mixed electronic/photonic circuits, develop interfaces with existing digital tools to enable co-simulation.

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- Moletronics. ($15.376 Million)
  - Characterize and optimize molecular-based devices such as switches, multi-state molecules and molecules exhibiting highly non-linear characteristics such as negative differential resistance.
  - Demonstrate that nano-wires have conductivities near that of bulk metal or better.
  - Quantify the defect-tolerance required for a molecular-based computer to still function.

(U) <u>FY 2003 Plans:</u>

- Quantum Information Science and Technology (QuIST). ($27.093 Million)
  - Develop models and scalable architectures for quantum communication and computation, including teleporting information over significant distances.
  - Explore challenges for scaling of bit rate-distance product for quantum secure fiber optic and free-space links via the design of repeaters that leverage teleportation and efficient sources.
  - Demonstrate robust single photon sources and detectors.
  - Determine quantum architecture and design solutions for problems such as graph isomorphism, imaging and signal processing.
  - Develop methods for simulating large quantum problems on a smaller quantum computer; applications to domains such as bond-selective chemistry.
  - Investigate the use of quantum information in clock synchronization and metrology.
  - Analyze the security of communication networks based on quantum key distribution.
  - Investigate error correction scalable to thousands of qubits.
  - Demonstrate scalable quantum computation and memory architectures.
  - Demonstrate active and passive control of coherent quantum states.
  - Demonstrate robust solid-state generation of Einstein, Podolsky, Rosen pairs.

- Polymorphous Computing Architectures. ($18.000 Million)
  - Model, simulate and characterize complete candidate polymorphic computing systems including hardware elements, morphware, run-time systems, and tools.
  - Perform early small scale proof-of-concept testing, integration and evaluation of early polymorphic computing architecture prototypes.

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- Demonstrate and quantify the potential of full up polymorphic computing architecture systems for the DoD and their complementary commercial viability.

- Antimonide Based Compound Semiconductors (ABCS). ($13.000 Million)
  - IR sources. Exploit the unique bandgap engineering approaches available with the ABCS family of materials to increase the operation temperature above 230 degrees Kelvin and extend emission over the Long-Wave Infrared (LWIR) range.
  - Achieve multi-watt output, array technology along with increases in efficiency for individual devices.
  - Deliver first six multi-batch ABCS substrates.

- Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD). ($14.000 Million)
  - Demonstrate the tools for designing and prototyping selected mixed electronic/photonic circuits and mixed signal systems (e.g., Analog-to-Digital Converters) for military applications.
  - Develop a design methodology for analog, mixed signal and mixed electronic/photonic systems utilizing:
    -- Analog behavioral models in a digital design environment.
    -- Extraction methodogies for analog and photonic devices.
    -- Synthesis and layout rules for analog and photonic devices.
    -- Hierarchical design libraries.

- Moletronics. ($15.331 Million)
  - Develop hierarchically directed assembly processes to assemble molecular devices, wires and interconnects.
  - Demonstrate efficient defect-search algorithms.
  - Model the scalability of molecular circuit architectures to high counts and high device densities.

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- Interconnected Nano-scale Electronics and Substrates (INES). ($7.575 Million)
  - Develop surface preparation and selective transfer processes for establishing templates on active substrates for direct interfaces with nano-scale devices and circuits.
  - Initiate development of fabrication technology for nano-scale switching devices.
  - Initiate interconnection of devices with high performance interfaces.

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

- Not Applicable.

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

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY	R-1 ITEM NOMENCLATURE
RDT&E, Defense-wide BA2 Applied Research	Materials and Electronics Technology PE 0602712E, Project MPT-09

COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Biologically Based Materials and Devices MPT-09	0.000	0.000	78.250	113.231	142.647	153.207	157.812	Continuing	Continuing

(U) Mission Description:

(U) This new project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials and devices as well as the commensurate influence of materials, physics and chemistry on new approaches to biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials for enhancement of performance, the development of multifunctional transducers based on biological membranes, and the application of magnetic materials in biological applications. This project contains efforts originating in Projects MPT-01, MPT-02 in this PE and maturing technologies from PE0601101E, Project BLS-01.

(U) The Bioderived Materials thrust explores the application of biomimetic principles to materials and devices of interest to the DoD. Specifically, the unique characteristics of biologically derived materials and devices will be exploited through understanding, control and emulation of the structure and chemistry of the interface between man-made and biotic materials. This includes an effort to develop synthetic optics that mimics the advantages and adaptability of biological lenses. Other efforts seek to understand the principles of locomotion and sensing capabilities of biological organisms and implement them in man-made materials for robotics and other Defense applications. Also, the fundamental operating principles of biomolecular motors will be developed and exploited for designing nano- to macro-scale devices having unparalleled energy efficiency.

(U) The Biochemical Materials thrust examines how breakthroughs in the understanding of biochemistry can drastically improve the capabilities of soldiers. For example, examining the biochemistry of the brain during sleep deprivation can lead to new approaches in enhancing performance in soldiers. The application of biochemical principles can also lead to understanding the physiology of the solider as he/she heads for battle and to developing techniques to allow the principles of biological organisms that survive in extreme environments to be exploited for the preservation of tissue and cells of interest to DoD. Approaches for employing solid, free-form computer-aided design techniques to build tissues are also being examined.

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(U) The goal of the Responsive Membrane Devices (REMEDE) program is to engineer bio-mimetic membrane technology for programmable, multifunctional biotransducers. This program will achieve advances over current state-of-the-art biochip technology and will advance synthetic membrane fabrication techniques, bio-related applications of nanotechnology, bio/solid-state interfaces, artificial cellular responses, induced membrane transport of ions and proteins, molecular recognition capabilities, and bio-mimetic signal amplification. A major goal of this program is to demonstrate an on-chip network of engineered membranes that mimic biological cellular response functions to an environmental stimulus.

(U) The Bio-Magnetic Interfacing Concepts (BioMagnetICs) Materials program will enable nanoscale magnetism to be integrated into biology and demonstrated as a new transduction mechanism for the detection and manipulation of single bio-molecules and cells and as an actuation mechanism for initiating and controlling many cellular functions. This program will result in a number of new DoD capabilities including highly discriminatory biosensing in noisy and variable chemical environments and novel diagnostics and therapeutic treatments for personnel.

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

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

- Not Applicable.

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

- Not Applicable.

(U) <u>FY 2003 Plans:</u>

- Bioinspired and Bioderived Materials. ($27.000 Million)
  - Determine the mechanism of motor function, motor performance and efficiency for several types of biomolecular motors.
  - Initiate biomolecular motor device design for several devices with potential DoD utility.
  - Fabricate and demonstrate new actuating materials for biomimetic appendage development.
  - Design, engineer and demonstrate new soft materials (e.g., actuators, adhesives) based on biological systems in Defense applications.
  - Explore biomimetic sensory fusion processing and integrate biomimetic sensors into mobile platforms.

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- Explore the controlled production of materials using biological systems such as engineered biochemical synthetic pathways and cell and tissue bioreactor plants.
- Demonstrate a synthetic bio-optical system using a bio-inspired lens with a variable index of refraction using materials chemistry and hierarchical structure.
- Explore new bioinspired locomotion in robotic systems.
- Examine systems level bio-locomotion for effeciency in power and mobility in rough terrain.
- Investigate materials for biologically-based fuel cells.

• Biochemical Materials. ($29.250 Million)
  - Explore production methods for manufacture of stable materials from organisms that survive environmental extremes.
  - Explore large-scale production methods for engineered cells with stabilized properties.
  - Identify gene and gene related materials that are associated with stress reduction and extended performance.
  - Demonstrate genes or gene products signatures that predict future physiologic status.
  - Understand pathways and explore biomedical technology required to enhance spatial orientation of the warfighter.
  - Develop self care medical technology to enable the warfighter in the battlefield to accelerate wound healing, hemostasis and pain relief to maintain a functional soldier.
  - Develop new tools and basic understanding of mitochondria for reversible enhancement of functional and physiokinetic endurance via nutritional, pharmaceutical and physical means.

• Responsive Membrane Devices (REMEDE). ($10.000 Million)
  - Demonstrate fabrication of on-chip artificial membranes with microfluidic capabilities.
  - Demonstrate controlled transport through membranes.

• Bio-Magnetic Interfacing Concepts (BioMagnetICs). ($12.000 Million)
  - Demonstrate the ability to selectively impart nanoscale magnetic moments to individual biomolecules and cells.
  - Demonstrate the ability to quantifiably identify and detect the low (less than a picogram per milliliter) presence of magnetically tagged molecules, including proteins, antibodies and nucleic acids.
  - Demonstrate the ability to magnetically trigger cellular responses such as apoptosis, protein expression and/or pigment change.

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– Demonstrate the advantages of a nanoscale biomagnetics transduction mechanism for addressing robustness, portability, and ease-of-use issues associated with providing fieldable devices to the DoD for biological and/or chemical detection, medical diagnostics, and therapeutics.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Advanced Aerospace Systems PE 0603285E, R-1 #36

COST *(In Millions)*	FY 2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	38.093	153.700	246.000	394.662	485.549	527.931	678.363	Continuing	Continuing
Advanced Aerospace Systems ASP-01	38.093	153.700	132.000	157.106	154.684	158.337	167.903	Continuing	Continuing
Space Programs and Technology ASP-02	0.000	0.000	114.000	237.556	330.865	369.594	510.460	Continuing	Continuing

(U) Mission Description:

(U) The Advanced Aerospace Systems program element is budgeted in the Advanced Technology Development budget activity because it addresses high payoff opportunities to dramatically reduce costs associated with advanced aeronautical and space systems and provide revolutionary new system capabilities for satisfying current and projected military mission requirements. Research and development of integrated system concepts, as well as enabling vehicle subsystems will be conducted.

(U) A number of aeronautical programs are funded in the Advanced Aerospace Systems project. The Supersonic Miniature Air-Launched Interceptor program will demonstrate an inexpensive supersonic air platform with a low cost infrared sensor to provide cruise missile defense. The A160 Hummingbird Warrior program will exploit a hingeless, rigid, rotor concept operating at the optimum rotational speed to produce a vertical take-off and landing unmanned air vehicle with very low disk loading and rotor tip speeds resulting in an efficient low power loiter and high endurance system. The Quiet Supersonic Platform program is directed towards development and validation of critical technology for long-range advanced supersonic aircraft with substantially reduced sonic boom, reduced takeoff and landing noise, and increased efficiency relative to current-technology supersonic aircraft.

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(U) Also funded within the Advanced Aerospace Systems project are several unmanned combat air vehicles. The Unmanned Combat Air Vehicle program continues to focus on risk reduction and "Concept of Operation" evaluation. The goal of the Naval Unmanned Combat Air Vehicle advanced technology demonstration program is to validate the technical feasibility for a naval unmanned combat air system to effectively and affordably perform naval Suppression of Enemy Air Defense/Strike/Surveillance missions. The goal of the Unmanned Combat Armed Rotocraft program is to design, develop, integrate and demonstrate the enabling technologies and system capabilities required to perform mobile strike concept of operations.

(U) The Space Programs and Technology Project focuses on a space force structure that is robust against attack. In addition to the ability to detect and characterize potential attacks, robustness against attack is provided by proliferation of assets, ready access to space and a flexible infrastructure for maintaining the capabilities of on-orbit assets. Ready access to space allows the delivery of defensive systems and replenishment supplies to orbit. An infrastructure to service the mission spacecraft allows defensive actions to be taken without limiting mission lifetime. The Orbital Express Space Operations Architecture program will develop and demonstrate autonomous techniques for on-orbit refueling and reconfiguration of satellites that could support a broad range of future U.S. national security and commercial space programs. The Space Surveillance Telescope program will develop and demonstrate an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability. The Innovative Space-Based Radar Antenna Technology program addresses the technical and economic feasibility of developing space-based radar antennas necessary for tactical-grade ground moving target indicator performance from space. The Space Vehicle Technologies program will pursue advances in space power, propulsion, maneuvering, navigation, communications and other spacecraft subsystems. The Advanced MEMS Technologies program seeks to demonstrate MEMS based technologies for space-based applications. Initially funded in the Tactical Technology program element in FY 2002, the Rapid Access, Small Cargo, Affordable Launch program that will develop and demonstrate the capability to launch small satellites and commodity payloads into low-earth orbit. The Tactical Optical Sensing program will develop both moving target indications over a wide area and high resolution imaging over a small area with the same optical sensor. The Low Cost Tactical Imager program will develop a spacecraft to provide high resolution imaging day or night using extremely lightweight optics and a compact design capable of being launched on a Pegasus air launch booster. The Tactical Pointing Determination of Imaging Spacecraft program will develop relocatable space surveillance radar to provide near-real time pointing determination of imaging spacecraft to the warfighter.

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

	FY 2001	FY 2002	FY 2003
FY02 Amended President's Budget	37.474	153.700	64.000
Current Budget	38.093	153.700	246.000

(U) Change Summary Explanation:

FY 2001 Increase reflects minor program repricing.

FY 2003 Increase reflects full funding of the Unmanned Combat Air Vehicle and major expansion of space programs initiated in FY 2002.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Aerospace Systems ASP-01	38.093	153.700	132.000	157.106	154.684	158.337	167.903	Continuing	Continuing

(U) Mission Description:

(U) The Advanced Aerospace Systems project addresses high payoff opportunities to dramatically reduce costs associated with advanced aeronautical systems and provide revolutionary new system capabilities for satisfying current and projected military mission requirements. Research and development of integrated system concepts, as well as enabling vehicle subsystems will be conducted.

(U) The A160 Hummingbird Warrior program will exploit a hingeless, rigid, rotor concept operating at the optimum rotational speed to produce a vertical take-off and landing (VTOL) unmanned air vehicle with very low disk loading and rotor tip speeds resulting in an efficient low power loiter and high endurance system. This unique concept offers the potential for significant increases in VTOL unmanned air vehicle (UAV) range (more than 2,000nm) and endurance (24-48 hours). Detailed design, fabrication and testing of this concept will be conducted to establish its reliability, maintainability and performance. The A160 concept is being evaluated for surveillance and targeting, communications and data relay, lethal and non-lethal weapons delivery, assured crew recovery and special operations missions in support of Navy, Marine Corps, Army and other Agency needs. In addition, this program will evaluate application of the optimum speed rotor concept to other systems including heavy lift and tilt rotor capabilities. The program will also develop highly efficient heavy fuel engine technologies to further advance current range and endurance projections as well as improve operational reliability and logistics compatibility.

(U) The Orbital Express Space Operations Architecture program will develop and demonstrate autonomous techniques for on-orbit refueling and reconfiguration of satellites that could support a broad range of future U.S. national security and commercial space programs. An important element of the program is the enabling nature of such capability for new space missions and its potential to reduce space program costs through spacecraft life extension ("Pre Planned Product Improvement," or "P3I"), comparable to what is done today with aircraft. During Phase I (Concept Definition) the type of satellite servicing to be emulated in the on-orbit demonstration will be identified (to include the type of hardware upgrades and reconfiguration to be supported, and the techniques to be adopted in transferring hardware and fuel between spacecraft), and detailed designs will be developed for "industry standard," nonproprietary satellite-to-satellite mechanical and electrical interfaces enabling on-orbit hardware and fluid transfers. Concepts for auxiliary missions for a servicing spacecraft, such as supporting operations of micro-satellites, will also be developed. A preliminary system design will emerge in conjunction with developments in software and sensors necessary for autonomous space operations to

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assess the potential significant cost savings for space operations. In Phase II, detailed design of the on-orbit demonstration spacecraft (the service vehicle, the demonstration "target," or serviced satellite, and the depot for replacement hardware and fuel) will occur and the spacecraft will be fabricated, integrated, ground tested, and space-qualified. In FY 2005, the demonstration spacecraft will be launched. On-orbit, the Orbital Express spacecraft will repeatedly demonstrate the feasibility of autonomously upgrading, refueling and reconfiguring satellites. Following an initial 4-6 month demonstration, the Orbital Express demonstration system will be transitioned to a follow-on customer for additional test and evaluation. In FY 2003, this program will be funded in Project ASP-02, Space Programs and Technology.

(U) The joint DARPA/Air Force Unmanned Combat Air Vehicle (UCAV) program will continue risk reduction and "Concept of Operation" evaluation for the Unmanned Combat Air Vehicle. Specifically, this program will continue the design and begin fabrication of the SystemB demonstrator (X-45B Low Observable air vehicle, mission control system and support segment), begin development of its tailored sensor and communications suite, and continue spiral system software development. Ultimately, this program will support the goal to demonstrate the technical feasibility, military utility and operational value of a UCAV system to effectively and affordably perform Suppression of Enemy Air Defense (SEAD)/Strike missions in the 2010 timeframe.

(U) The goal of the Naval Unmanned Combat Air Vehicle (UCAV-N) advanced technology demonstration program is to validate the technical feasibility for a naval unmanned combat air system to effectively and affordably perform naval Suppression of Enemy Air Defense (SEAD)/Strike/Surveillance missions within the emerging global command and control architecture. This advanced technology demonstration initiative will investigate and validate the critical technologies, processes and system attributes associated with the development of a UCAV-N system. The proposed UCAV-N design will be suitable for aircraft carrier use; however, will also stress maximum commonality with the Air Force UCAV. Analysis of the legacy force carrier air wing together with an additional 12 to 16 multi-mission Strike, SEAD and Surveillance unmanned combat aircraft that are suitable for aircraft carrier use and capable of penetrating fully operational enemy air defense systems are areas of investigation. It is also important to develop and demonstrate a low life cycle cost combat effective design for a multi-mission Strike, Suppression of Enemy Air Defense (SEAD) and Surveillance unmanned air vehicle while demonstrating robust and secure command, control and communications peculiar to the maritime environment, including line-of-sight, non-line-of-sight, and over-the-horizon.

(U) The Quiet Supersonic Platform (QSP) program is directed towards development and validation of critical technology for long-range advanced supersonic aircraft with substantially reduced sonic boom, reduced takeoff and landing noise, and increased efficiency relative to current-technology supersonic aircraft. Improved capabilities include supersonic flight over land without adverse sonic boom consequences with boom overpressure rise less than 0.3 pounds per square foot, increased unrefueled range approaching 6,000 nmi, gross take-off weight approaching

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100,000 pounds, increased area coverage and lower overall operational cost. Highly integrated vehicle concepts will be explored to simultaneously meet the cruise range and noise level goals. Advanced airframe technologies will be explored to minimize sonic boom and vehicle drag including natural laminar flow, aircraft shaping, plasma, heat and particle injection, and low weight structures.

(U) Both the U.S. military and economy increasingly depend on space platforms for command, control, communications, intelligence, surveillance, reconnaissance, meteorology, navigation and other functions. With this increasing dependence comes increased vulnerability to attack on space platforms and their ground based infrastructures. This project is also developing technologies that enable survivable and robust space systems. The project consists of: Space Protection and Warning (SPAWN); Space Battle Management Command, Control and Communications ($SBMC^3$); and Deep View. The SPAWN, $SBMC^3$, and Deep View programs are closely coordinated with the Air Force and USCINCSPACE, and with DARPA's Advanced Space Surveillance Telescope (PE0603762E, Project SGT-02), Orbital Express, and classified programs.

(U) The Satellite Protection and Warning (SPAWN) program will examine the use of microsatellites to provide enhanced situational awareness for U.S. space assets. Functions will include self-inspection, characterization, space environment monitoring, and diagnosis of spacecraft anomalies. A key element of this program will be the use of a modular satellite architecture to enable rapid integration of multiple payload combinations in response to varying mission requirements. In Phase I, a range of satellite warning and protection functions will be analyzed and ranked in order of utility, such as situational awareness, self-inspection, and characterization. A preliminary system design will detail the number, types and configurations of sensors as well as the software required for characterization and assessment, which will generate status reports and anomaly alerts. A high degree of autonomous operation, with reporting only on significant events or requests from the ground, will be a key objective. In Phase II, detailed designs of the on-orbit demonstration spacecraft will occur and the spacecraft will be fabricated, ground tested, and space-qualified. Finally, in FY 2005, the SPAWN demonstration spacecraft will be launched and engaged in a series of on-orbit demonstrations. In FY 2003, this program will be funded in Project ASP-02, Space Programs and Technology.

(U) The Space Battle Management Command, Control and Communications ($SBMC^3$) program will develop computing and communications technologies that will enable space forces to dominate the battlespace through automated spacecraft tracking and control, fusion of space surveillance sensor information, and assured command and control of space assets. $SBMC^3$ will provide algorithms that enable correlation and handoff of data between space sensors of widely different sensing modalities, locations and reporting intervals. Protocols for information exchange within the space control architecture will be optimized. Information systems for highly automated space object tracking, identification and activity assessment will be developed. The space battle management architecture will feature streamlined human interaction for more rapid action timelines

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and reduced error rates, in an environment of ever increasing numbers of sensors being controlled and objects being tracked, while maintaining assured human control of space activities. In FY 2003, this program will be funded in Project ASP-02, Space Programs and Technology.

(U) The Deep View program (formerly entitled the "Space Object Identification System") will develop a high-resolution radar imaging capability to characterize objects in earth orbit. A special emphasis will be placed on imaging small, faint objects at orbits ranging from low-earth orbit to geo-stationary orbit. The system will be based upon a large aperture imaging radar system redesigned to operate at very high power over very broad bandwidth at W-band. Key technology development will focus on transmitters capable of providing the required power to image to GEO over full bandwidth and antenna design that maintains necessary form factor over a very large aperture. The capabilities emerging from this program will enable the classification of unknown objects, such as space debris, as well as the monitoring of the health and status of operational satellites. In FY 2003, this program will be funded in Project ASP-02, Space Programs and Technology.

(U) The Space Technologies Program will develop and demonstrate advances in smart materials, multifunctional materials and power electronics to provide gains in the performance of space structures and systems. This work will include materials, devices and novel structural systems that will allow for large scale changes in shape and function with minimal energy/power requirements for shape control, and adaptation on-orbit to precisely align highly packaged spacecraft. This task will also demonstrate an electronics module that utilizes the hybridization of cryogenic, superconducting and conventional room temperature power electronics for optimum performance of satellite systems. This hybridization translates to modules with increases of efficiency of factors of two to four, at least ten times lower system noise and significant reductions in size and weight that scale with the overall size of the system.

(U) The goal of the Unmanned Combat Armed Rotorcraft (UCAR) program is to design, develop, integrate and demonstrate the enabling technologies and system capabilities required to perform the mobile strike concept of operations within the Army's Objective Force system-of-systems environment. The enabling technologies are survivability, autonomous operations, command and control, and targeting/weapons delivery. A highly survivable UCAR system will prosecute enemy high value targets with relative impunity without placing a pilot in harm's way. In addition, a UCAR capability will provide the Objective Force with the mobility, responsiveness, and lethality required to ensure mission success. Specific objectives of the UCAR program include: development and demonstration of an effective, low total ownership cost design for the UCAR system; an air and ground-based command and control architecture for UCAR operations; autonomous multi-ship cooperation and collaboration; autonomous low altitude flight; and UCAR system survivability.

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(U) The Supersonic Miniature Air-Launched Interceptor (MALI) program demonstrated an inexpensive supersonic air platform with a low cost infrared (IR) sensor to provide cruise missile defense by exploiting large rear aspect IR signatures and overtaking incoming missiles from the rear. The program leveraged off the miniature air-launched decoy (MALD) program's technology and off board surveillance and tracking sensors to provide tail-on missile end game opportunities. An advanced unmanned air vehicle avionics development and emerging payload effort was incorporated into the MALI core program due to the required data transmit/receive survivability configuration of the interceptor mission.

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

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

- Advanced Air Vehicle: Hummingbird Warrior. ($3.700 Million)
  - Initiated ground and flight test-phase of A160 air vehicle.
  - Designed sensor integration modifications to A160 air vehicle.
  - Designed low-vibration rotor modifications for A160.
  - Designed unmanned ground vehicle deployment system for A160.
  - Studied A160 scaling and signature reduction.

- Supersonic Miniature Air-Launched Interceptor (MALI). ($7.708 Million)
  - Completed air vehicle fabrication, assembly and conducted ground testing.
  - Completed engine and infrared payload testing.
  - Demonstrated inter-vehicle communications, mission processing and execution capability.
  - Performed supersonic engine flight verification and seeker/advanced payload verification.
  - Conducted demonstration of subsonic vehicle interceptor and collaborative formation flying mission.
  - Conducted flight intercept demonstration against a representative target.
  - Continued to explore alternative mission concepts for low cost MALI airframes, including ground-launched variant of interceptor vehicle for use by land forces.

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- Orbital Express Space Operations Architecture. ($6.825 Million)
  - Continued the identification, definition and analysis of the requirements for on-orbit satellite servicing.
  - Continued to analyze the utility, cost effectiveness and life-cycle costs.
  - Continued redefinition of the Operational System Concept.
  - Continued nomination process of a baseline satellite-servicing mission.
  - Continued to define a servicing concept of operations.
  - Defined a draft, non-proprietary satellite-to-satellite interface standard.
  - Performed risk reduction research and development activities of critical items.
  - Completed initial demonstration test plan.
  - Conducted preliminary design review and developed request for proposals in preparation for Phase II.

- Quiet Supersonic Platform. ($19.860 Million)
  - Continued development of technologies for long-range supersonic aircraft having low sonic boom and noise signature, range augmentation through low vehicle drag and system weight reduction.
  - Developed conceptual designs for highly integrated supersonic long-range aircraft.

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

- Advanced Air Vehicle: Hummingbird Warrior. ($15.000 Million)
  - Fabricate and test low vibration rotor modifications for A160 air vehicle.
  - Continue ground and flight test of A160.
  - Integrate/demonstrate electro-optic/infrared surveillance payload on A160 vehicle.
  - Concept design of unmanned ground vehicle deployment system on A160 vehicle.
  - Perform conceptual design and trade studies of a rotorcraft variant of the unmanned combat air vehicles developed under this project, including study of technology risk reduction, architecture, survivability and command and control sensor development.

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- Orbital Express Space Operations Architecture. ($31.700 Million)
  - Complete Phase I.
  - Conduct Source Selection and initiate Phase II of the demonstration system.
  - Complete demonstration system detailed design including standard (non-proprietary) satellite-to-satellite electrical and mechanical interfaces.
  - Define objectives for micro-satellite operations in the Phase II on-orbit demonstration.
  - Develop key enabling technologies and continue risk reduction activities.
  - Initiate fabrication of demonstration system/subsystems.
  - Initiate auto guidance, navigation and control system and software design.

- Unmanned Combat Air Vehicle (UCAV). ($60.000 Million)
  - Complete conceptual layout design phase and begin detailed design/long lead procurement of a third air vehicle (X-45B), which incorporates integrated apertures and antennas, integrated weapons, distributed avionics, low observable (LO) treatments and exhaust, and increased functionality.
  - Conduct high-fidelity component radar cross-section analysis, define LO treatment suite, and initiate large-scale component test article design and fabrication.
  - Initiate development of an advanced electronic support measures subsystem, synthetic aperture radar, and satellite communication terminal tailored for the X-45B.
  - Complete design of a fully interoperable mission control system architecture incorporating multilevel security features in both hardware and software.
  - Complete conceptual layout design phase and begin detailed design/long lead procurement of the X-45B container and support equipment.

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- Naval Unmanned Combat Air Vehicle (UCAV-N). ($27.000 Million)
  - Conduct demonstrations of technologies, processes, and systems attributes to demonstrate the feasibility of UCAV operation from ships.
  - Conduct maritime network centric warfare.
  - Initiate detailed design of a demonstrator aircraft.

- Quiet Supersonic Platform. ($1.000 Million)
  - Perform validation of technologies for long-range supersonic aircraft having low noise signature.

- Satellite Protection and Warning (SPAWN). ($5.000 Million)
  - Define requirements for a micro (50 to 100 kg) satellites to provide enhanced situational awareness for national security satellites.
  - Multiple awards of Phase I concept definition efforts.
  - Identify candidate sensor technologies and characterization techniques, select approaches for further development.
  - Devise architectures and concept of operations; determine the feasibility and utility of these missions.
  - Perform risk reduction research and development activities of critical items.

- Space Battle Management Command, Control and Communications (SBMC^3). ($5.000 Million)
  - Define computing and communication interfaces with legacy systems.
  - Devise computing and communication architectures and concept of operations; determine effectiveness in high tempo scenario with modeling and simulation.
  - Identify candidate algorithms and technologies to mitigate high-risk areas, select approaches for further development.
  - Initiate the design, development, and integration of proof-of-principle algorithms and technologies.

- Deep View. ($5.000 Million)
  - Perform initial radar system design.
  - Perform analysis of transmitter technology alternatives.
  - Analyze antenna design requirements.

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- Space Technologies. ($4.000 Million)
  - Initiate feasibility studies; develop conceptual designs and figures of merit for morphing/shape control of space vehicles.
  - Develop multifunctional structure concepts for reducing weight, improving survivability and adaptively changing capability of space structures.
  - Initiate design for integrated hybrid power module and quantify performance improvements in powering radio frequency , microwave and optical system.

(U) **<u>FY 2003 Plans:</u>**

- Advanced Air Vehicle: Hummingbird Warrior. ($9.000 Million)
  - Continue flight tests of A160 air vehicles.
  - Fabricate forward pass mini control station for A160.
  - Demonstrate forward pass operations with Electro-Optic/Infrared (EO/IR) on A160.
  - Flight test low vibration four-blade rotor modifications for A160.
  - Develop advanced airframe helo modification for A160.
  - Investigate application of the optimum speed rotor (OSR) concept to tilt rotor aircraft, including preliminary design of an unmanned system.
  - Develop high-efficiency heavy fuel engine technologies.

- Unmanned Combat Air Vehicle (UCAV). ($60.000 Million)
  - Continue design and begin component fabrication of the X-45B air vehicle, mission control system and container.
  - Continue development of an advanced electronic support measures subsystem, synthetic aperture radar, and satellite communication terminal tailored for the X-45B.
  - Define the Block 4 system software requirements for integrating dynamic replanning/low observable auto-routing and multi-vehicle cooperative targeting decision aids into the air vehicle mission management system.

- Naval Unmanned Combat Air Vehicle (UCAV-N). ($25.000 Million)
  - Continue development and demonstration of technologies to operate from ships and unprepared areas ashore.

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- Complete detailed design and initiate construction of demonstrator aircraft.

- Quiet Supersonic Platform. ($15.000 Million)
  - Perform trade-studies and mission utility analysis.
  - Conduct integration experiments and demonstrations of enabling technologies.
  - Initiate preliminary system designs of highly integrated supersonic long-range aircraft.

- Unmanned Combat Armed Rotorcraft (UCAR). ($23.000 Million)
  - Complete Phase I and select up to two teams for Phase II development.
  - Develop UCAR preliminary design, risk management plan, and technology and system maturation plan.
  - Continue system trades, effectiveness, and affordability through modeling and simulation.
  - Develop sufficient system concept fidelity to validate program goals and objectives.

(U) Other Program Funding Summary Cost:

- Advanced Air Vehicle: Hummingbird Warrior:

	FY 2001	FY 2002	FY 2003
SOCOM	0.500	1.000	0.000

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- Unmanned Combat Air Vehicle (UCAV):

Air Force	24.800	21.100	58.000

- Naval Unmanned Combat Air Vehicle (UCAV-N):

Navy	1.500	15.000	25.000

(U) Schedule Profile:

Plan	Milestones
Advanced Air Vehicle (AAV):	
Apr 02	A160 Electro-Optic/Infrared payload first flight.
Jul 02	A160 Higher Harmonic Control Rotor system first flight.
Sep 02	Complete initial concept design and trades studies of rotorcraft variant of an unmanned combat air vehicle.
Jun 03	A160 Compound Helo Design Review.
Jun 03	A160 Flight with Forward Pass Ground Control Station.
Miniature Air-Launched Interceptor (MALI):	
Feb 02	Supersonic Intercept Free Flight demonstration.
Orbital Express Space Operations Architecture:	
Mar 02	Conduct Delta preliminary design review.
Jun 02	Conduct Critical Design Review.
Aug 02	Begin subsystem fabrication; complete system level simulator for integrated software testing.
Nov 02	Begin subsystem level environmental qualification testing; initiate fabrication of ASTRO and NextSat satellites.

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Unmanned Combat Air Vehicle (UCAV):

Mar 02	System B Interim Design Review.
Sep 02	System B mid-term Design Review.
Jan 03	Begin System B long lead fabrication.
Sep 03	System B Final Design Review.
Oct 03	Block 4 Software Requirements Review.

Naval Unmanned Combat Air Vehicle (UCAV-N):

Apr 02	Conduct 12 percent low speed wind tunnel test.
Sep 02	Conduct 12 percent high-speed wind tunnel test.
Sep 02	Complete Distributed Control, AWACS/JSTARS and laboratory demonstration.
Nov 02	Demonstration and evaluation of Human Systems Interface Devices (HSI) in laboratory and maritime environment.
Dec 02	Complete Radar cross section Signature demonstration complete.
Jul 03	Complete deck operations demonstration.
Jul 03	Complete mission control system Navy C4I infrastructure integration demonstration.
Oct 03	Contractor X and Y UCAV-N Demonstration System (UDS) construction complete.
Dec 03	Conduct Next Generation synthetic aperature radar technology flight demonstration.
Dec 03	Contractor Y final UDS ground tests complete.

Quiet Supersonic Platform (QSP):

Aug 02	Complete laminar flow control supersonic wind tunnel tests.
Sep 02	Complete advanced structures experiment.
Dec 02	Complete Mission Vehicle Concept Definition.
Jan 03	Complete Shaped Sonic Boom Demonstration and Analysis.
Sept 03	Complete Engine Rig 1 Testing.

Space Battle Management Command, Control and Communications (SBMC^3):

Jul 02	Complete interface definition documentation.
Nov 02	Select teams for spacecraft hardware and ground segment automation.

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Deep View:

May 02	Complete preliminary design review.
Jul 02	Select transmitter technology.
Mar 03	Complete transmitter performance analysis.

Satellite Protection and Warning (SPAWN):

Feb 02	Initiate mission analysis and architecture studies.
Jun 02	Release Phase I solicitation for Concept Definition and Design Studies.
Sep 02	Multiple Phase I awards to industry teams.

Unmanned Combat Armed Rotorcraft:

Apr 02	Initiate Phase 1 Study.
Sep 02	Initial System Architecture Definition.
Mar 03	System Requirements Review.
Dec 03	Preliminary Design Review.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Space Programs and Technology ASP-02	0.000	0.000	114.000	237.556	330.865	369.594	510.460	Continuing	Continuing

(U) **Mission Description:**

(U) A space force structure that is robust against attack represents a stabilizing deterrent against adversary attacks on space assets. In addition to the ability to detect and characterize potential attacks, robustness against attack is provided by proliferation of assets, ready access to space, and a flexible infrastructure for maintaining the capabilities of on-orbit assets. Ready access to space allows the delivery of defensive systems and replenishment supplies to orbit. An infrastructure to service the mission spacecraft allows defensive actions to be taken without limiting mission lifetime. In addition, developing space access and spacecraft servicing technologies will lead to reduced ownership costs of space systems and new opportunities for introducing technologies for the exploitation of space. Systems development is also required to increase the interactivity of space systems, space-derived information and services with terrestrial users. Because of the increasing national importance of this area, and the expanded resource allocations devoted to it, a separate project, ASP-02, has been created. Ongoing space-related programs in Advanced Aerospace Systems (Project ASP-01), Tactical Technology (Project TT-06) and Sensors and Guidance Technology (Projects SGT-02 and 03) in addition to new efforts, are now funded in this newly created project.

(U) The Orbital Express Space Operations Architecture program will develop and demonstrate autonomous techniques for on-orbit refueling and reconfiguration of satellites that could support a broad range of future U.S. national security and commercial space programs. An important element of the program is the enabling nature of such capability for new space missions and its potential to reduce space program costs through spacecraft life extension (“Pre Planned Product Improvement,” or “P3I”), comparable to what is done today with aircraft. During Phase I (Concept Definition) the type of satellite servicing to be emulated in the on-orbit demonstration will be identified (to include the type of hardware upgrades and reconfiguration to be supported, and the techniques to be adopted in transferring hardware and fuel between spacecraft), and detailed designs will be developed for “industry standard,” nonproprietary satellite-to-satellite mechanical and electrical interfaces enabling on-orbit hardware and fluid transfers. Concepts for auxiliary missions for a servicing spacecraft, such as supporting operations of micro-satellites, will also be developed. A preliminary system design will emerge in conjunction with developments in software and sensors necessary for autonomous space operations to assess the potential significant cost savings for space operations. In Phase II, detailed design of the on-orbit demonstration spacecraft (the service vehicle, the demonstration “target,” or serviced satellite, and the depot for replacement hardware and fuel) will occur and the spacecraft will be fabricated, integrated, ground tested, and space-qualified. In FY 2005, the demonstration spacecraft will be launched. On-orbit, the Orbital Express

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spacecraft will repeatedly demonstrate the feasibility of autonomously upgrading, refueling and reconfiguring satellites. Following an initial 4-6 month demonstration, the Orbital Express demonstration system will be transitioned to a follow-on customer for additional test and evaluation. This program was previously funded in FY 2002 in Project ASP-01, Advanced Aerospace Systems.

(U) The Space Surveillance Telescope program will develop and demonstrate an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability. The program will leverage recent advances in curved focal plane array technology and large, light-weight optics to build a telescope with a large aperture that provides detection sensitivity with a low-aberration wide field-of-view to provide rapid wide-area search coverage. Advances in lightweight optics will reduce the size and weight of the telescope, providing fast slewing and further increasing search rates. This capability will enable ground-based detection of un-cued objects in space for purposes such as asteroid detection and other defense missions. In FY 2002, this program was funded in PE 0603762E, Project SGT-02, Aerospace Surveillance Technology.

(U) The Innovative Space-Based Radar Antenna Technology (ISAT) effort will build on the FY 2002 conceptual designs addressing the technical and economic feasibility of developing space-based radar antennas necessary for tactical-grade ground moving target indication performance from space using rigidized inflatable technologies – a potentially key enabling technology. During FY 2003, DARPA will develop two competing conceptual designs, including a detailed technical design and focused testing of key design components such as flexible transmit/receive modules, thin-film solar cells, and membrane designs. Additionally, DARPA will conduct ground-based risk reduction experiments demonstrating the accuracy of the constitutive models for deployment and control of rigidized inflatable structures. DARPA will also develop performance predictions on the selected designs as well as lifecycle cost models. In FY 2002, a series of studies to prepare for this activity was funded in PE 0603762E, Project SGT-03, Air Defense Initiative.

(U) The Satellite Protection and Warning (SPAWN) program will examine the use of microsatellites to provide enhanced situational awareness for U.S. space assets. Functions will include self-inspection, characterization, space environment monitoring, and diagnosis of spacecraft anomalies. A key element of this program will be the use of modular satellite architecture to enable rapid integration of multiple payload combinations in response to varying mission requirements. In Phase I, a range of satellite warning and protection functions will be analyzed and ranked in order of utility, such as situational awareness, self-inspection, and characterization. A preliminary system design will detail the number, types and configurations of sensors as well as the software required for characterization and assessment, which will generate status reports and anomaly alerts. A high degree of autonomous operation, with reporting only on significant events or requests from the ground, will be a key objective. In Phase II, detailed designs of the on-orbit demonstration spacecraft will occur and the spacecraft will be fabricated, ground tested, and

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space-qualified. Finally, in FY 2005, the SPAWN demonstration spacecraft will be launched and engaged in a series of on-orbit demonstrations. In FY 2002, this program was funded in Project ASP-01, Advanced Aerospace Systems.

(U) The Space Battle Management Command, Control and Communications ($SBMC^3$) program will develop computing and communications technologies that will enable space forces to dominate the battlespace through automated spacecraft tracking and control, fusion of space surveillance sensor information, and assured command and control of space assets. This program will provide algorithms that enable correlation and handoff of data between space sensors of widely different sensing modalities, locations, and reporting intervals. Protocols for information exchange within the space control architecture will be optimized. Information systems for highly automated space object tracking, identification, and activity assessment will be developed. The space battle management architecture will feature streamlined human interaction for more rapid action timelines and reduced error rates in an environment of ever increasing numbers of sensors being controlled and objects being tracked, while maintaining assured human control of space activities. In FY 2002, this program was funded in Project ASP-01, Advanced Aerospace Systems.

(U) The Deep View program will develop a high-resolution radar imaging capability to characterize objects in earth orbit. A special emphasis will be placed on imaging small, faint objects at orbits ranging from low-earth orbit (LEO) to geo-stationary (GEO) orbit. The system will be based upon a large aperture imaging radar system redesigned to operate at very high power over very broad bandwidth at W-band. Key technology developments will focus on transmitters capable of providing the required power to image to GEO over full bandwidth and antenna design that maintains necessary form factor over a very large aperture. The capabilities emerging from this program will enable the classification of unknown objects, such as space debris, as well as the monitoring of the health and status of operational satellites. In FY 2002, this program was funded in Project ASP-01, Advanced Aerospace Systems.

(U) The Space Vehicle Technologies (SVT) program will pursue advances in breakthrough technologies for space power, propulsion, maneuvering, navigation, communications and other spacecraft subsystems. Technologies will be selected that can provide revolutionary enhancements in space-based mission performance and/or dramatic reductions in space vehicle ownership costs. Projects involving technologies that support new missions, including on-orbit servicing, space surveillance, and defense of space assets, will also be undertaken. Integration of commercially available technologies into space hardware and software will be explored, and new techniques, processes, materials and software will be developed where required. Radical approaches to prelaunch test and space qualification will also be explored. The capabilities resulting from the SVT program will enable new military missions not previously viewed as practicable from space, as well as enabling current space missions to be conducted in a more efficient and survivable manner.

(U) The Advanced MEMS Technologies program seeks to demonstrate microelectromechanical systems (MEMS) based technologies for

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space based applications such as a miniature spacecraft capable of maneuvering outside a satellite to perform a number of functions including inspection of the mother craft or of nearby objects. Beyond the requirements for electrical powering, communications, guidance and imaging technology, these MEMS picosatellites would require propulsion systems based on MEMS thrusters and would possibly include MEMS structures for thermal control.

(U) The Responsive Access, Small Cargo, Affordable Launch (RASCAL) program will develop and demonstrate the capability to launch small (under 110 pounds) satellites and commodity payloads into low-Earth orbit on demand and for a total launch cost of $10,000 per pound or less. This capability will enable cost effective use of on-orbit replacement and re-supply. This capability will also provide a means for rapid launch of orbital assets for changing national security needs. While the payload cost goal is commensurate with current large payload launch systems, it is more than a factor of five less than current capabilities for dedicated launch of payloads of this small size. This program will utilize reusable aircraft technology for the first stage and will take advantage of low-cost hybrid advanced rocket fuel technologies for the expendable upper stages. With recent advances in design tools and simulations this program will prudently reduce design margins and trade-off system reliability to maximize cost effectiveness. This program will also leverage advancements in autonomous range safety; first-stage guidance; and predictive vehicle health diagnosis, management and reporting to lower the recurring costs of space launch. In FY 2002, this program was funded in Project TT-06, Advanced Tactical Technology.

(U) The Tactical Optical Sensing (TOS) program will develop and demonstrate technology to give the battlefield commander both moving target indications over a wide area and high resolution imaging over a small area, using a single optical sensor. This combination of capabilities in a single system enables true tactical use of space-based optical sensors, allowing the U.S. to move quickly from a surveillance mode to a target tracking and identification mode. This program will develop foveating-imaging techniques that have a large field of view at coarse resolution combined with a narrow field of view at fine resolution. The program will also develop techniques for carrying out moving target identification with optical sensors. Along with these technology developments, a demonstration system will be designed, built and flown in 2007.

(U) The Low Cost Tactical Imager (LCTI) program will develop a space-based sensor to provide high-resolution, day/night Earth-imaging using extremely lightweight optics and a compact design capable of being launched on a Pegasus air launch booster. By meeting the payload constraints of the Pegasus booster, LCTI will provide the capability to launch covertly on demand - anywhere, anytime, into any orbit - to defeat camouflage, concealment and deception techniques. Weight reduction of the optical system is a key enabler of this concept; it will be achieved by using diffractive optics to reduce the weight of the primary by an order of magnitude, and the weight of the system by half. If successful, this will be the first-ever use of diffractive optics for a reconnaissance application, and it will require the largest Fresnel lens built to date.

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(U) The Tactical Pointing Determination of Imaging Spacecraft (TPDIS) program will develop relocatable space surveillance radar to provide near-real time pointing determination of imaging spacecraft to the warfighter. Today, theater commanders are warned of enemy imaging spacecraft overflights. However, there is no capability to determine where the spacecraft were tasked to collect imagery. TPDIS will develop an order of magnitude improvement in resolution and accuracy over the current state of the art to provide position and pointing information of space-based imagers. This capability will offer warfighters indic ation and warning of enemy observations of U.S. and allied forces.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Not Applicable.

(U) FY 2002 Plans:

- Not Applicable.

(U) FY 2003 Plans :

- Orbital Express Space Operations Architecture. ($30.000 Million)
  - Initiate fabrication of Autonomous Space Transfer and Robotic Orbiter (ASTRO) and Next Generation Satellite (NEXTSat).
  - Continue auto guidance, navigation and control system and software design; initiate testing on system simulators.
  - Perform critical technology/subsystem tests on Orbital Express hardware.
  - Begin integration and ground testing of Orbital Express system/subsystems.

- Space Surveillance Telescope. ($6.000 Million)
  - Begin fabrication of telescope optics and mount.
  - Complete focal plan fabrication.

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- Innovative Space-Based Radar Antenna Technology (ISAT). ($11.000 Million)
  - Select two competitive architectures, based on FY 2002 conceptual designs.
  - Refine performance and cost models for each candidate design and associated technologies.
  - Perform focused risk-reduction experiments on key technologies associated with selected conceptual designs.
  - Carry out ground-based experiments to validate FY 2002 modeling and simulation of rigidized inflatable technologies.

- Satellite Protection and Warning (SPAWN). ($6.000 Million)
  - Conduct preliminary design review and develop Request for Proposals in preparation for Phase II.
  - Conduct Source Selection and initiate Phase II of the demonstration system.
  - Initiate fabrication of demonstration system/subsystems.

- Space Battle Management Command, Control and Communications (SBMC^3). ($3.000 Million)
  - Complete proof-of-principle algorithms.
  - Test performance of algorithms against simulated and recorded data.
  - Initiate development of system testbed.
  - Incorporate performance models for advanced sensors into architecture analysis.

- Deep View. ($4.000 Million)
  - Begin transmitter component design and transmitter performance analysis.
  - Complete radar system design.
  - Complete antenna control design.
  - Begin image processing software development.

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- Space Vehicle Technologies (SVT). ($2.000 Million)
  - Identify candidate technologies for high payoff space application; select approaches for further development.
  - Award Phase I Concept Definition studies.

- Advanced MicroElectroMechanical Systems (MEMS). ($6.000 Million)
  - Demonstrate MEMS based Joule-Thompson and other approaches to micro-fluidic techniques to realize micro-coolers for critical electronic components.

- Responsive Access, Small Cargo, Affordable Launch (RASCAL). ($25.000 Million)
  - Phase 1 down select/Phase II source selection.
  - Mission cycle testing of the first-stage reuseable launch vehicle propulsion in wind tunnel.
  - Establish Preliminary and Critical Design of full system.
  - Continue to refine performance and cost models.
  - Early Risk Reduction testing of subsystems.
  - Integration of low cost expendable rocket vehicle and common head steering stage design.

- Tactical Optical Sensing. ($7.000 Million)
  - Develop candidate designs for dual-mode, foveal imaging sensor.
  - Develop performance models for candidate designs.
  - Initiate foveated imaging and optical moving target indications risk reduction technology development.
  - Initiate conceptual designs of a space-based foveal imaging sensor.

- Low Cost Tactical Imager. ($8.000 Million)
  - Develop candidate designs for low-cost, light-weight imaging system.
  - Estimate performance for candidate designs
  - Initiate diffractive optics technology risk reduction efforts.

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- Tactical Pointing Determination of Imaging Spacecraft. ($6.000 Million)
  - Initiate development of W-band technology risk reduction testbed.
  - Begin design of relocatable surveillance radar.

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

	FY 2001	FY 2002	FY 2003
Orbital Express: UPN 721-40 NASA Marshall Space Flight Center	0.000	10.000	10.000

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

Plan	Milestones
Orbital Express Space Operations Architecture:	
Jan 03	Complete alpha version of flight software; begin testing on satellite software simulator.
May 03	Complete beta version of autonomous guidance, navigation and control software; begin testing in full motion simulation facility.
Sep 03	Begin payload integration testing into Autonomous Space Transfer and Robotic Orbiter (ASTRO) and Next Generation Satellite buses.
Space Surveillance:	
Jan 03	Focal plane tile fabrication and initial testing complete.
Sep 03	Telescope optics layout complete.
Innovative Space-Based Radar Antenna Technology (ISAT):	
Oct 02	Down-select Conceptual Designs.
Dec 02	Begin Key Component Risk-Reduction Experiments.
May 03	Demonstrate Controlled Deployment and Rigidization Process Verifying Constitutive Equations.
Aug 03	Preliminary Design Reviews.

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Sep 03 Final Technical Report on Preliminary Designs.

Satellite Protection and Warning (SPAWN):
Jun 03 Conduct Phase I final reviews.
Aug 03 Conduct Release solicitation for Phase II detailed design and fabrication.

Space Battle Management Command, Control and Communications (SBMC^3):
Nov 02 Select teams for spacecraft hardware and ground segment automation.
Jul 03 Complete proof-of-concept algorithm design.
Sept 03 Complete proof-of-concept algorithm testing.

Deep View:
Mar 03 Complete transmitter performance analysis.
Jun 03 Complete critical design review.

Space Vehicle Technologies (SVT):
Jan 03 Select teams for technology development projects.
Jun 03 Complete agreements with launch providers and technology demonstration bus programs for on-orbit testing of technologies.

Advanced MicroElectroMechanical Systems (MEMS).
Sep 03 Demonstrate MEMS based approaches to micro-fluidic techniques to realize micro-coolers for electronic components.

Responsive Access, Small Cargo, Affordable Launch (RASCAL):
Apr 03 Preliminary Design Review.
Jul 03 Critical Design Review.
Jul 03 Cost Model Feasibility Tool.
Oct 03 System Level Design.
Oct 03 Down select Phase I.

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Tactical Optical Sensing

Jan 03	Select teams for technology development efforts.
Aug 03	Complete conceptual system design.

Low Cost Tactical Imager

Jan 03	Select teams for technology development efforts.
Aug 03	Complete conceptual system design.

Tactical Pointing Determination of Imaging Spacecraft

Jan 03	Initiate risk reduction activity.
Aug 03	Complete preliminary system design.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	213.379	199.564	150.400	148.070	143.776	143.492	143.211	Continuing	Continuing
Uncooled Integrated Sensors MT-03	12.776	6.441	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Electronic Module Technology MT-04	38.963	35.000	21.699	31.807	29.747	29.688	29.630	Continuing	Continuing
Centers of Excellence MT-07	5.213	5.000	4.000	0.000	0.000	0.000	0.000	0.000	N/A
Advanced Lithography MT-10	54.457	36.632	25.000	25.000	25.000	0.000	0.000	0.000	N/A
MEMS and Integrated Micro-systems Technology MT-12	46.730	40.783	28.000	19.804	19.725	19.792	19.753	Continuing	Continuing
Mixed Technology Integration MT-15	55.240	75.708	71.701	71.459	69.304	94.012	93.828	Continuing	Continuing

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

(U) The Advanced Electronics Technology program element is budgeted in the Advanced Technology Development Budget Activity because it seeks to design and demonstrate state-of-the-art manufacturing and process technologies for the production of various electronics and microelectronic devices, sensor systems, actuators and gear drives that have military applications and potential commercial utility. Introduction of advanced product design capability and flexible, scalable manufacturing techniques will enable the commercial sector to rapidly and cost-effectively satisfy military requirements and enhance the U.S. industrial base.

(U) The Uncooled Integrated Sensors project addresses a long-standing Defense requirement for uncooled infrared sensor arrays for major weapons systems that cannot accommodate costly cryogenic cooling packages.

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(U) The Electronic Module Technology project is a broad initiative to decrease the cost and increase the performance of weapon systems through the insertion of electronic modules. Electronic module technology addresses the design and fabrication of various types of digital, analog and mixed signal modules consisting of electronic, electro-optical and micro-mechanical components. Included in this project is the Semiconductor Ultraviolet Optical Sources, the Superconducting Hybrid Power Electronics (SuperHyPE), and the Very High Speed Digital and the Mixed Signal Microsystems initiatives.

(U) Advanced Lithography technology has enabled the dramatic growth of integrated circuit capability. Advances have led to improvements in electronic and computing systems performance in terms of speed, power, weight and reliability. Further improvements require microcircuits with smaller features to meet the operational speed, power, weight and volume constraints.

(U) The Microelectromechanical Systems (MEMS) and Integrated Microsystems Technology project is a broad and cross-disciplinary initiative to develop an enabling technology that merges computation with sensing and actuation to realize new systems for both perceiving and controlling weapons systems, processes and battlefield environments. Using fabrication processes and materials similar to those that are used to make microelectronic devices, MEMS conveys the advantages of miniaturization, multiple components and integrated microelectronics to the design and construction of integrated electromechanical systems. The microfluidic molecular systems program will address issues centered around the development of automated microsystems that integrate biochemical fluid handling capability along with electronics, opto-electronics and chip-based reaction and detection modules to perform tailored analysis sequences for monitoring of environmental conditions, health hazards and physiological states.

(U) The goal of the Mixed Technology Integration project is to revolutionize the integration of mixed technologies at the micrometer/nanometer scale. This will produce low-cost, lightweight, low-power 3-D microsystems that improve battlefield awareness and the operational performance of military platforms. This project will leverage industrial manufacturing infrastructure to produce mixed-technology microsystems that will revolutionize the way warfighters see, hear, taste, smell, touch and control environments. Efforts in this project include Self-Synchronized Noise Systems Program, the Digital Control of Analog Circuits Program and the Anti-Tamper initiative.

(U) The Centers of Excellence (MT-07) project finances demonstration, training and deployment of advanced manufacturing technology at Marshall University and the Defense Techlink Rural Technology program. This effort will complete during FY 2003.

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

	FY 2001	FY 2002	FY 2003
FY02 Amended President's Budget	219.467	177.264	159.867
Current Budget	213.379	199.564	150.400

(U) **Change Summary Explanation:**

FY 2001 Decrease reflects the SBIR reprogramming and the Omnibus transfer.

FY 2002 Increase reflects congressional adds in Advanced Lithography Demonstration, Laser Plasma Point Source, X-Ray Mask Research, Novel Crystal Components for Imaging and Communications, and Defense Techlink.

FY 2003 Decrease reflects completed funding of the Uncooled Integrated Sensors project and reduced funding requirements of the Micro Power Generation program.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Uncooled Integrated Sensors MT-03	12.776	6.441	0.000	0.000	0.000	0.000	0.000	0.000	N/A

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

(U) The Uncooled Integrated Sensors project addresses the technology necessary to produce affordable, infrared sensor arrays essential to major weapon systems. The focal plane array consists of a two-dimensional detector array sensitive in a broad spectral range, integrated with unique signal processing to enhance performance and provide more efficient utilization of the information. The critical elements of the technology addressed in this program include the infrared material, detector array fabrication, read-out electronics, cryogenic packaging and testing, and module assembly. Processing and fabrication techniques focus on the production of affordable arrays, at low volume, in the configurations required by weapon systems. Performance enhancements in uncooled infrared and near-infrared sensors are also being addressed to provide an integrated, broadband two-dimensional sensor array without the cryogenic package usually associated with infrared sensors.

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

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

- Uncooled Imaging Sensors & Devices. ($8.804 Million)
  - Demonstrated 100 gram imaging sensor with performance acceptable for micro-air-vehicles.
  - Optimized read-out structure to read signals with short (approximately 1 msec.) integration time.
  - Conducted three-D thermal imaging phenomenological experiments and studies.

- Electro-Optics IR Technology Center. ($3.972 Million)
  - Developed the next generation infrared and night vision sensor technology, consisting of large arrays of multi-spectral detectors, with integral signal processing, addressing systems' needs for threat warning and target acquisition.
  - Incorporated innovative detector and signal processor designs to maximize operating temperature, while maintaining the target discrimination capability at the maximum system range.

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(U) FY 2002 Plans:

- Uncooled Imaging Sensors & Devices. ($6.441 Million)
  - Incorporate high responsitivity materials into detector structure.
  - Integrate materials and microstructure into imaging device.

(U) FY 2003 Plans:

- Not Applicable.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Mar 02	Integrate materials and microstructure into imaging device.
Sep 02	Demonstrate five-gram sensor with sensitivity < 10 milli-Kelvin, ideal thermal imaging device.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Electronic Module Technology MT-04	38.963	35.000	21.699	31.807	29.747	29.688	29.630	Continuing	Continuing

(U) **Mission Description:**

(U) The Electronic Module Technology Project is a broad initiative to substantially decrease the cost and increase the performance of weapon systems through the timely insertion of state-of-the-art electronic modules. Electronic module technology addresses the design and fabrication of various types of digital, analog and mixed signal modules consisting of electronic, electro-optical and micro-mechanical components. It includes traditional approaches such as printed circuit boards, and emerging technologies such as high density Multichip Modules. The project has three major objectives: (l) shorten the overall design, manufacture, test and insertion cycle for advanced electronic subsystems; (2) advance the state-of-the-art in electronic interconnection and physical packaging technology to allow circuits to operate close to their intrinsic maximum speed with less overhead in terms of volume, weight and cost; and (3) provide a robust manufacturing infrastructure for electronic modules.

(U) The Electronic Module Technology project has the following major elements: Photonic Analog/Digital (A/D) Conversion; Distributed Robotics; Design Support for Mixed Technology Integration (Composite CAD), the Molecular-level Large-area Printing (MLP), Semiconductor Ultraviolet Optical Sources (SUVOS) program and the Superconducting Hybrid Power Electronics (SuperHyPE) program. Photonic Analog/Digital (A/D) conversion will utilize breakthrough photonic developments to substantially increase the speed that analog signals are converted into digital data streams for data reduction and processing. Distributed Robotics is an effort to integrate developments in Microelectromechanical Systems (MEMS), power sources, communications and advanced microelectronics to design, construct and field multiple, high-performance, mobile, autonomous systems. Composite CAD seeks to develop the design tools (concept exploration, analysis, optimization and verification) to allow thousands of analog, digital, optical, MEMS and microfluidic devices to be integrated into “systems-on-a-chip” and other highly integrated mixed technology systems. The MLP program demonstrated approaches to ‘printing’ MEMS devices on large surfaces.

(U) The Semiconductor Ultraviolet Optical Sources (SUVOS) program will develop photonic wide band gap materials for optical emission in the ultraviolet for bio sensing, and covert communications applications. This program will develop high conductivity *p*-type (positive charge carrier) material, and highly efficiently active region material suitable for ultraviolet emission and exploit these results to enable the development of heterojunction bipolar transistors (HBT).

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(U) An initiative in Very High Speed Digital & Mixed Signal Microsystems will address key issues to accelerate Indium Phosphide (InP) technology for the purpose of satisfying emerging DoD needs, while leveraging the pull of the potential commercial (primarily fiber optic communications) marketplace. This program, in two broad thrusts, will develop a manufacturable InP technology to demonstrate wide dynamic range mixed signal circuits operating at clock frequencies in the neighborhood of 100 GHz.

(U) Hybrid superconducting/cryogenic components will provide a new paradigm for power electronics for the "all electric" platforms of the future. Recent breakthroughs in high temperature superconducting wires will now allow superconducting power components to work effectively at temperatures as high as 77°K. Combining these superconducting components (motors, generators, energy storage devices, transmission lines, inductors, limiters) with cryogenic semiconducting power electronics will provide: a) improved controllability (via rapid response and ease of interface with digital control systems); b) significantly reduced maintenance; c) reduced complexity (reduced number of energy transformations, reduced support requirements); d) increased efficiency (less energy conversion, improved primary power sources); e) new applications (pulsed energy systems, directed energy weapons, rail guns) and last but not least, f) reduced personnel needs (fully automatic systems). These hybrid systems offer significant increases in specific power density that provide weight and volume savings that scale with the overall size of the system. This can easily translate to factors of two to three savings for a moderate size system (5000 HP) and an order of magnitude for large systems (greater than 20,000 HP). The Superconducting Hybrid Power Electronics (SuperHYPE) program will build a prototype system of moderate size that will be fully integrated from generator to load and will be operated at the optimum temperature for each subsystem.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Photonic A/D. ($13.802 Million)
  - Completed initial photonic analog/digital (A/D) converter evaluation and finalized design for demonstration module.
  - Demonstrated key photonic technologies.

- Distributed Robotics. ($12.678 Million)
  - Demonstrated multiple robots with overall functionality and probability of mission success improved by integration of optimized control strategies.

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- Molecular-level Large-area Printing (MLP). ($12.483 Million)
  - Demonstrated and characterized 10,000 x 100 pixel density array on a spherical surface.

(U) **FY 2002 Plans:**

- Photonic A/D. ($10.557 Million)
  - Complete photonic analog/digital converter technology development.
  - Integrate photonic clock and sampler modules with electronic quantizers.
  - Complete analog/digital converters with at least 10 gigasamples/sec.
  - Demonstrate high linearity and dynamic range.

- Distributed Robotics. ($5.749 Million)
  - Complete current contracts on micro robot developments.
  - Deliver prototype hardware and final reports.
  - Demonstrate with operational military users.

- Semiconductor Ultraviolet Optical Sources (SUVOS). ($13.228 Million)
  - Demonstrate *p*-type (positive charge carrier) doping in high aluminum concentration nitride materials at concentrations sufficient for minority carrier injection devices.

- Superconducting Hybrid Power Electronics (SuperHyPE). ($5.466 Million)
  - Identify target power modules and platform for maximum benefit of hybrid approach.
  - Initiate design for integrated hybrid power module.

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(U) <u>FY 2003 Plans:</u>

- Semiconductor Ultraviolet Optical Sources (SUVOS). ($13.600 Million)
  - Demonstrate minority carrier devices (e.g. light emitting diodes, laser diodes, heterojunction bipolar transistors).

- Very High Speed Digital & Mixed Signal Microsystems. ($3.099 Million)
  - Develop current Indium Phosphide - Integrated Circuit (InP-IC) technology to higher levels of complexity and push InP mixed signal IC technology to extreme speed (while maintaining useful breakdown voltage and noise margin).
  - Demonstrate wide dynamic range mixed signal circuits of ~ 1000 transistors.

- Superconducting Hybrid Power Electronics (SuperHYPE). ($5.000 Million)
  - Demonstrate hybrid superconducting power modules for 1 kW (satellite) and 500 kW (shipboard) with high efficiency, reliability, and reduced size and weight.

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

- Not Applicable.

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

<u>Plan</u>	<u>Milestones</u>
Jul 02	Develop high power high temperature devices.
Sep 02	Demonstrate high temperature operation of integrated power switches.
Jul 03	Achieve wide-dynamic range mixed signal circuits of 10,000 transistors.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Centers of Excellence MT-07	5.213	5.000	4.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) This project provides funding for the Robert C. Byrd Institute for Advanced Flexible Manufacturing at Marshall University. The Byrd Institute provides both a teaching factory and initiatives to local area industries to utilize computer-integrated manufacturing technologies and managerial techniques to improve manufacturing productivity and competitiveness. Training includes technologies to significantly reduce unit production and life cycle costs and to improve product quality. This project also includes funding for the Defense Techlink Rural Technology Transfer Project.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Advanced Flexible Manufacturing. ($ 3.972 Million)
  - Continued to expand the web based electronics supply chain and increased the number of manufacturers who have access to, and qualify for, Defense acquisitions.

- Defense Techlink Rural Technology Transfer Project. ($ 1.241 Million)
  - Provided funding for the Defense Techlink Rural Technology Transfer Project.

(U) FY 2002 Plans:

- Advanced Flexible Manufacturing. ($ 4.000 Million)
  - Continue assessment of the Institute for Advanced Flexible Manufacturing's performance and transition from DoD to state/private support.

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- Defense Techlink Rural Technology Transfer Project. ($ 1.000 Million)
  - Continue to provide funding for the Defense Techlink Rural Technology Transfer Project.

(U) <u>FY 2003 Plans:</u>

- Advanced Flexible Manufacturing. ($ 4.000 Million)
  - Complete assessment of the Institute for Advanced Flexible Manufacturing's performance and transition from DoD to state/private support.

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

- Not Applicable.

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

<u>Plan</u>	<u>Milestones</u>
Sep 03	Complete assessment and transition of the Institute for Advanced Flexible Manufacturing from DoD to state/private support.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Lithography MT-10	54.457	36.632	25.000	25.000	25.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) Microelectronics is a key to improved weapon system performance. Lithography technology has enabled the dramatic growth in microelectronics capability over the past three decades. The improved capabilities in semiconductor technology contribute to significant system gains in speed, reliability, cost, power consumption and weight. Advanced microelectronics technology is essential for computing and signal processing in virtually all military systems including command, control, communications and intelligence; electronic warfare; and beam forming for radar and sonar. Further improvements in areas such as target recognition, autonomous guided missiles and digital battlefield applications require microcircuits with smaller features to meet the operational speed, power, weight and volume constraints of these systems.

(U) Current microelectronics fabrication utilizes feature sizes of 0.18 microns. The Advanced Lithography program emphasizes longer-term research with expected high payoff in the fabrication of semiconductor devices with 0.05 or less micron feature sizes. These efforts will develop technology for sub 0.05 micron features.

(U) The goal of the Advanced Lithography program is to reduce technical barriers to the development of advanced lithographic technologies for the fabrication of a broad range of microelectronic devices and structures. Innovative research in pattern generation and transfer, imaging materials, new process and metrology will provide alternatives beyond current evolutionary trends. The program will investigate technologies for the creation of highly complex patterns at sub 0.05 μm resolution over field areas in excess of 1000 mm^2. Applications with larger geometries will be explored for innovative devices and structures beyond microelectronics, including nanolithography.

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

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

- Sub 0.1 Micron Lithographies. ($23.031 Million)
  - Demonstrated key components of maskless wafer writer and key components for lithography of 0.07 micron features.

- Support Technologies. ($17.822 Million)
  - Accelerated technology developments in the lithography exposure sources and supporting (cross-cutting) technologies needed for microelectronics fabrication.
  - Reduced risks in key areas of components, materials and processing allowing industry to fabricate prototype tools and new high-performance devices for use in advanced military systems and commercial markets.

- Laser Plasma X-Ray Source. ($4.965 Million)
  - Continued laser plasma x-ray source technology.

- Point Source Lithography. ($3.674 Million)
  - Continued point source lithography development.

- Advanced Lithography Mask Development. ($4.965 Million)
  - Continued lithography mask development.

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

- Sub 0.1 Micron Lithographies. ($14.532 Million)
  - Develop key tool components, materials and processing for both maskless and projection approaches for lithography at 0.05 microns and below.
  - Fabricate prototype devices for military applications with features at 0.1 micron.

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- Support Technologies. ($10.000 Million)
  - Develop mask technology (writing, inspection and repair), resists and metrology for lithography for sub 0.1 micron.
  - Develop thinner resists appropriate for emerging exposure sources.

- Laser Plasma X-Ray Source. ($4.300 Million)
  - Continue laser plasma x-ray source technology.

- Advanced Lithography Development. ($4.300 Million)
  - Continue point source lithography development.

- Advanced Lithography X-Ray Mask Development. ($3.500 Million)
  - Continue lithography X-Ray mask development.

(U) **<u>FY 2003 Plans:</u>**

- Sub 0.1 Micron Lithographies. ($15.000 Million)
  - Develop and demonstrate key subsystems for both maskless and projection approaches for lithography technologies that will extend to 0.05 microns and below.
  - Fabricate prototype tools for fabrication of devices with 0.07 micron features.
  - Explore nanolithography with features down to the range of 10 nm.

- Support Technologies. ($10.000 Million)
  - Develop mask technology (writing, inspection and repair), resists and metrology for lithography for 0.05 micron and below.
  - Exploit advances from longer term developments in direct write-on-wafer projects.

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

- Not Applicable.

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

Plan	Milestones
Aug 02	Demonstrate key components for lithography of 0.07 micron features.
Sep 02	Demonstrate key components for mask writer for sub 0.1 micron features.
Aug 03	Demonstrate prototype tool for fabrication of devices with 0.07 micron features.
Aug 04	Demonstrate key components for fabrication of devices with 0.05 micron features.
Aug 05	Demonstrate prototype tool for fabrication of devices with 0.05 micron features.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
MEMS and Integrated Micro-systems Technology MT-12	46.730	40.783	28.000	19.804	19.725	19.792	19.753	Continuing	Continuing

(U) **Mission Description:**

(U) The Microelectromechanical Systems (MEMS) program is a broad, cross-disciplinary initiative to develop an enabling technology that merges computation and power generation with sensing and actuation to realize a new technology for both perceiving and controlling weapons systems and battlefield environments. Using fabrication processes and materials similar to those that are used to make microelectronic devices, MEMS provides the advantages of miniaturization, multiple components and integrated microelectronics to the design and construction of integrated electromechanical and electro-chemical-mechanical systems. The MEMS program addresses issues ranging from the scaling of devices and physical forces to new organization and control strategies for distributed, high-density arrays of sensor and actuator elements. These issues include microscale power and actuation systems as well as microscale components that survive harsh environments. The microfluidic molecular systems program will develop automated microsystems that integrate biochemical fluid handling capability along with electronics, optoelectronics and chip-based reaction and detection modules to perform tailored analysis sequences to monitor environmental conditions, health hazards and physiological states.

(U) The MEMS program has three principal objectives: the realization of advanced devices and systems concepts; the development and insertion of MEMS into DoD systems; and the creation of support and access technologies to catalyze a MEMS technology infrastructure. These three objectives cut across a number of focus application areas to create revolutionary military capabilities, make high-end functionality affordable to low-end systems and extend the operational performance and lifetimes of existing weapons platforms. The major technical focus areas for the MEMS program are: 1) inertial measurement; 2) fluid sensing and control; 3) electromagnetic and optical beam steering; 4) mass data storage; 5) chemical reactions on chip; 6) electromechanical signal processing; 7) active structural control; 8) analytical instruments; and 9) distributed networks of sensors and actuators.

(U) Compact portable power sources capable of generating power in the range of a few hundred milliwatts to one watt are critical to providing power for untethered sensors and other chip-scale microsystems. This program aims to replace today's technologies relying on primary and rechargeable batteries, which severely limit mission endurance and capabilities, by extending microelectronic machine technology to develop micro-

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power generators based on mechanical actuation and thermal-electric power generation. Operating with traditional fuels, these micropower generators will be capable of generating sustained power in the desired range for use with remote, field-deployed microsensors and microactuators.

(U) Within this project is the development of totally integrated microfluidic chips to enable ubiquitous yet unobtrusive assessment of the warfighter's body fluids. These microchips integrate detection, diagnostics and treatment in one chip-scale system called Bio-Fluidic chips.

(U) A new initiative in chip-scale micro-coolers aims to demonstrate MEMS Technology for fabrication of chip-scale micro-cooling elements.

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

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

- MEMS Micro Power Generation. ($18.907 Million)
  - Demonstrated chip-level integration of components for fuel processing, thermal management, energy conversion and exhaust management for micropower generation. Enabled stand alone, remotely distributed microsensors with built-in power supply and RF communication in addition to various sensing functions.
  - Developed MEMS free-piston knock engine.
  - Developed an integrated fuel cell and fuel processor for microscale power generation from liquid fuels.
  - Developed integrated chemical fuel microprocessor for power generation in MEMS applications.
  - Developed 3-D monolithically fabricated thermoelectric micro generator.

- CAMD. ($2.731 Million)
  - Continued micro device manufacturing process at the Center for Advanced Microstructures and Devices (CAMD).

- Deep Silicon Etching. ($7.944 Million)
  - Continued MEMs Deep Etching program in conjunction with the Army Research Laboratory.

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- Bio-Fluidic Chips (BioFlips). ($17.148 Million)
  - Developed closed-loop bio-fluidic chips to regulate cellular transduction pathways and precise dosage of chemicals/drugs/ reagents/enzymes.
  - Fabricated and tested individual microfluidic chip components and integrated sensors for flow control.
  - Manipulated (pump/valve/sense) bio-fluids in integrable microfluid components.

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

- MEMS Micro Power Generation. ($18.804 Million)
  - Demonstrate capabilities in fuel processing, energy conversion to electricity, thermal and exhaust management.
  - Demonstrate MEMS micro heat engines utilizing micropower sources.

- Bio-Fluidic Chips (BioFlips). ($16.779 Million)
  - Demonstrate optimization of sub-systems and components for integration into prototype systems. Sub-systems include: 1) on-chip sample preparation and processing (on-chip flow/concentration regulators, biosignal amplification, on-chip pressure sources, on chip separation/mixing, reagents storage/reconstitution); 2) sample collection (body fluid extractors, concentrators); and 3) antidote synthesis (genetic and antibodies) subsystems.
  - Identify partners in the DoD and other federal agencies for testing prototype systems.
  - Perform preliminary testing of prototype systems for re-evaluation of sub-system functionality.

- Deep Silicon Etching. ($5.200 Million)
  - Complete MEMS Deep Etching program in conjunction with Army Research Laboratory.

(U) <u>FY 2003 Plans:</u>

- MEMS Micro Power Generation. ($9.512 Million)
  - Demonstrate integration of various power-generation components with microsensors and microactuators.
  - Demonstrate stand alone, remotely distributed microsensors and actuators with built-in power supply and wireless communication.

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- Bio-Fluidic Chips (BioFlips). ($13.317 Million)
  - Modify sub-systems based on preliminary testing of prototype systems.
  - Finalize testing of prototype systems to optimize integrated performance.
  - Demonstrate prototype BioFlip systems in field insertions.

- Chip Scale MEMS Micro-Cooler. ($5.171 Million)
  - Demonstrate MEMS Technology for fabrication of chip-scale cooling elements.

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

- Not Applicable.

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

<u>Plan</u>	<u>Milestones</u>
Jul 02	Demonstrate BioFlips optimization of sub-systems and components.
Feb 02	Demonstrate micro heat engines.
Aug 03	Demonstrate electrical power generation.
Aug 03	Test and optimize BioFlips prototype.
Sep 03	Demonstrate stand-alone microsensors with integrated micropower source and wireless communication.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development					R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-15			
COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Mixed Technology Integration MT-15	55.240	75.708	71.701	71.459	69.304	94.012	93.828	Continuing	Continuing

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

(U) The goal of the Mixed-Technology Integration project is to leverage advanced microelectronics manufacturing infrastructure and DARPA component technologies developed in other projects to produce mixed-technology microsystems that will revolutionize the way individuals see, hear, taste, smell, touch and control their environment at a distance. These 'wristwatch size', low-cost, lightweight and low power microsystems will improve the battlefield awareness and security of the warfighter and the operational performance of military platforms. At the present time, systems are fabricated by assembling a number of mixed-technology components: Microelectromechanical Systems (MEMS), microphotonics, microfluidics and millimeterwave/microwave. Each technology usually requires a different level of integration, occupies a separate silicon chip and requires off-chip wiring, fastening and packaging to form a module. The chip assembly and packaging processes produce a high cost, high power, large volume and lower performance system. This program is focused on the monolithic integration of mixed technologies to form batch-fabricated, mixed technology microsystems 'on-a-single-chip' or an integrated and interconnected 'stack-of-chips'.

(U) The field of microelectronics incorporates micrometer/nanometer scale integration and is the most highly integrated, low-cost and high-impact technology to date. Microelectronics technology has produced the microcomputer-chip that enabled or supported the revolutions in computers, networking and communication. This program extends the microelectronics paradigm to include the integration of heterogeneous or mixed technologies. This new paradigm will create a new class of 'matchbook-size', highly integrated device and microsystem architectures. Examples of component-microsystems include low-power, small-volume, lightweight, microsensors, microrobots and microcommunication systems that will improve and expand the performance of the warfighter, military platforms, munitions and UAVs.

(U) The program includes the integration of mixed materials on generic substrates including glass, polymers and silicon. The program is design and process intensive, using 'standard' processes and developing new semiconductor-like processes and technologies that support the integration of mixed-technologies at the micrometer/nanometer scale. The program includes the development of micrometer/nanometer scale isolation, contacts, interconnects and 'multiple-chip-scale' packaging for electronic, mechanical, fluidic, photonic and rf/mmwave/microwave technologies. For example, a mixed-technology microsystem using integrated microfluidics, MEMS, microphotonics, microelectronics and microwave components could provide a highly integrated, portable analytical instrument to monitor the battlefield environment, the physical

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condition of a warfighter, the identity of warfighters (friend or foe) or the combat readiness of equipment. The ability to integrate mixed technologies onto a single substrate will drive down the size, weight, volume and cost of weapon systems while increasing their performance and reliability.

(U) The 3-Dimensional Imaging Devices program is developing new high speed imaging devices and array technology to rapidly acquire high resolution (less than 6 inches in range) three dimensional images of tactical targets at ranges of 7 to 10 kilometers, thereby increasing identification range of tactical targets, especially from fast moving platforms.

(U) The Steered Agile Laser Beams (STAB) program is developing small, lightweight laser beam scanning technologies for the replacement of large, heavy gimbaled mirror systems. New solid state/micro-component technologies such as optical MEMs, patterned liquid crystals and diffractive micro-optics will be used to build small, ultra-light, rapidly steered laser beam sub-systems.

(U) The Radio Frequency (RF) Lightwave Integrated Circuits (RFLICS) program is demonstrating enhanced performance capabilities of RF systems enabled by integration of lightwave and RF technologies to route, control, and process analog RF signals in the 0.5 – 50 Ghz range.

(U) The Nano Mechanical Array Signal Processors (NMASP) will create arrays of precision, nano mechanical structures for radio frequency (RF) signal processing that will greatly reduce the size and power consumption of various communication systems.

(U) The goal of the Chip Scale Wavelength Division Multiplexing (WDM) program is to develop new materials, components and sub-systems for use in wavelength division multiplexing based optical communications, delivering high capacity, mission adaptable networks for use in data intensive military weapons systems.

(U) The objective of the Multi-function Imaging Micro-systems program is to develop and demonstrate a new class of uncooled low power, light weight sensors, with an integral intelligent imaging capability, including target discrimination, multi-spectral band imaging, sensor radiation shielding and on-chip signal processing.

(U) The Self-Synchronized Noise Systems program will exploit advances in nano-scale CMOS, high speed Si-Ge and MEMS RF filter technologies to demonstrate the capability to generate, detect, and process chaotic (noise-like) electromagnetic signals that have self-synchronization

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properties. The effort will develop high performance signal generators and detectors (correlators, convolution processors, filter, etc.) that implement and invert chaotic functions that have self-synchronization properties.

(U) Digital Control of Analog Circuits will demonstrate analog/RF electronic components with the ability to self-assess and adapt in real time (sub microseconds), by self-tuning its impedance-matched networks, extending the operational performance of analog components to the intrinsic semiconductor device limits. This technology will result in a new generation of analog, microwave and millimeter wave components with >150X improvements in power-bandwidth, linearity-efficiency products.

(U) The goal of the Anti-Tamper (AT) initiative is to protect selected critical technologies in U.S. weapons systems that may be developed with or sold to foreign governments or that could possibly fall into enemy hands. Specifically, AT is intended to prevent technology transfer, alteration of system capability, and development of countermeasures due to weapon system co-development, sales, or potential loss on the battlefield. An AT technology base will develop complimentary AT techniques with broad applicability across the range of DoD critical technologies. Areas of AT technology interest include software, digital electronics, materials, and systems operating across the electromagnetic spectrum.

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

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

- 3-D Imaging Devices. ($20.980 Million)
  - Completed design of high-speed electronics for sub-nanosecond detection.
  - Initiated experiments in exploiting and adapting emerging technology in nanofabrication to create nano resonators by chemical and physical transfer of materials on nano-scale patterns.
  - Integrated high-speed electronics with 5x5-detector array and integrated into brass board imaging system.
  - Demonstrated laboratory imaging with 5x5 array.
  - Selected detector design for 128x128 3-D imaging array.

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- Steered Agile Laser Beams (STAB). ($17.840 Million)
  - Developed electronically steered laser beam technology for use in covert, anti-jam, high bandwidth battlefield communications - hand held ground-to-ground recon units that are able to transmit images and geo-location data of targets, and for use in target designators for small unit operations in high threat environments.
  - Fabricated beam steering emitters and detectors.

- RF Lightwave Integrated Circuits (RFLICS). ($16.420 Million)
  - Focused program on key applications for integrated RF-Photonic modules and produced initial prototypes and demonstrated methods for evaluation of their performance.
  - Initiated parallel efforts to develop components for efficient RF links exhibiting better than zero net loss and to demonstrate the advantages of integrated optical-RF modules for RF systems.
  - Down-selected among technology options and developed prototype module for demonstration.

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

- 3-D Imaging Devices. ($12.711 Million)
  - Demonstrate range imaging at the eye-safe wavelength of 1.54 micrometers, with a minimum array size of 64x64. The goal is target identification range of 10 km with single laser pulse imaging.
  - Demonstrate 480 x 640 array with 20 mk sensitivity.
  - Investigate polarization structures, with uncooled arrays.
  - Integrate photon and thermal detectors on the same chip, with dual mode read-out.

- Steered Agile Laser Beams (STAB). ($12.339 Million)
  - Analyze system concepts that will be used to develop design goals for assembled components.
  - Fabricate individual laser beam steering components (lasers, diffractive optics, micro electro-mechanical (MEMS) sub-assemblies, detectors, filters and integrated circuits).
  - Resolve component interface issues in preparation for breadboard development.

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- RF Lightwave Integrated Circuits (RFLICS). ($10.661 Million)
  - Determine the quantitative performance requirements of computationally intensive weapons systems tasks such as RF channnelization, local oscillator distribution, antenna beam forming, jammer nulling, and signal synthesis and frequency conversion.
  - Use results of earlier RF photonics single chip development effort to establish goals for RF photonic component fabrication.
  - Integrate recently developed emitters, waveguides, detectors and integrated circuits to produce RF photonic component prototypes.

- Nano Mechanical Array Signal Processor (NMASP). ($10.686 Million)
  - Demonstrate fabrication techniques to control surface morphology, geometry, and material properties at the sub-micron scale.
  - Demonstrate temperature stability and electrical tenability of individual nano resonators suitable for UHF communication.
  - Initiate development of nano mechanical array signal processors that will enable ultra miniaturized (wristwatch or hearing aid in size) and ultra low power UHF communicators/GPS receivers.

- Digital Control of Analog Circuits RF Front Ends. ($6.916 Million)
  - Demonstrate real-time active self-assessment and monitoring of RF/analog functions using nano-CMOS digital and mixed-signal technologies to achieve stability, signal agility, and multifunctionality.
  - Design processes to fabricate arrays of molecular flow control devices including interconnect microfluidics and electronics.

- Chip Scale Wavelength Division Multiplexing (WDM). ($8.395 Million)
  - Conduct modeling, simulation and analysis of artificial dielectrics and new materials for ultra-compact Wavelength Division Multiplexing (WDM) components.
  - Conduct experimental efforts in the growth and fabrication of these new materials and determine suitable processing procedures.
  - Plan construction of WDM components.

- Anti-Tamper (AT). ($8.000 Million)
  - Facilitate information exchanges throughout the Services, DoD Agencies and Labs and industry to preclude development of duplicative technologies.
  - Develop an interactive AT databank and library.
  - Develop a technology roadmap required to prioritize the overall technological research and development effort.

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- Develop AT technology throughout the Radio/Frequency/Gallium Arsenide and Digital Gallium Arsenide domains.

- Novel Crystal Components for Imaging and Communications. ($6.000 Million)
  - Initiate component development.

(U) **FY 2003 Plans:**

- Steered Agile Laser Beams (STAB). ($10.463 Million)
  - Evaluate competing laser beam steering component technologies; down-select to the most promising approaches.
  - Complete prototype design studies.
  - Assemble and test components suitable for use in prototype demonstration and evaluation.
  - Assess performance characteristics of the prototypes and make recommendations for future development.

- RF Lightwave Integrated Circuits (RFLICS). ($5.707 Million)
  - Complete the design and fabrication of RF photonic prototypes.
  - Construct testbeds capable of producing realistic systems demands for the demonstration and evaluation of RF lightwave integrated circuit components and assemblies.
  - Measure and analyze the operational impact of the photonic domain for advanced RF signal transmission, conditioning and processing.

- Nano Mechanical Array Signal Processor (NMASP). ($15.000 Million)
  - Demonstrate several alternatives to achieve uniform arrays of up to 1024 nano resonators with geometrical control and material uniformity at $\pm$20%, and to $\pm$1% with trimming and tuning.
  - Demonstrate interconnection and isolation (multiplexed, serial, or random access) of individual resonators.

- Chip Scale Wavelength Division Multiplexing (WDM). ($13.000 Million)
  - Design, fabricate and test novel WDM components using the new materials and processing technology.
  - Determine fiberoptic and planar waveguide interconnection requirements.

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- Evaluate the suitability of the new components for use in prototype modules.
- Down-select to the most promising approaches and begin prototype module assembly.
- Construct testbeds capable of fully measuring and characterizing the new technologies implemented in the chip-scale WDM components.
- Evaluate the performance characteristics of the prototype modules and determine the highest payoff dual use development paths.

• Digital Control of Analog Circuits RF Front Ends. ($7.000 Million)
- Develop techniques and algorithms to monitor active device status.
- Demonstrate MEMs tunable device optimization (<1 microsecond, 10:1 tuning ratio).
- Fabricate tunable MEMs control Integrated Circuits (ICS).
- Fabricate self-assessment control Integrated Circuits (ICS).

• Multi-Function Imaging Microsystems. ($12.000 Million)
- Demonstrate 320 x 240 photon detector array integrated with a microbolometer array.
- Demonstrate 320 x 240 imaging with solid state radiation shield temperature reduction of 20 K.
- Demonstrate mid wave room temperature array 320 x 240 with sensitivity suitable for imaging.

• Self-Synchronized Noise Systems. ($8.531 Million)
- Demonstrate capability to detect and process chaotic electromagnetic signals.
- Develop high performance signal generators and detectors.

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

• Not Applicable.

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(U) Schedule Profile:

Plan	Milestones
3-D Imaging:	
Jun 02	Demonstrate range imaging at eye safe wavelengths.
STAB:	
Jul 02	Fabricate laser beam steering components.
May 03	Complete prototype design studies.
RFLICS:	
Aug 02	Integrate emitters, waveguides and detectors into RF photonic component prototypes.
Sep 03	Complete design and fabrication of RF photonic prototypes.
WDM:	
Aug 02	Develop artificial dielectrics suitable for compact WDM modules.
Aug 03	Design, fabricate, and test WDM modules.
NMASP:	
Jul 02	Demonstrate electrically controlled tunability suitable for UHF communication.
Aug 03	Demonstrate arrays up to 1024 nano resonators with geometrical control and material uniformity at $\pm$20%, and to $\pm$1% with trimming and tuning.
Digital Control:	
Jul 02	Demonstrate RF/analog functions using mixed-signal technologies.
Jun 03	Demonstrate MEMS tunable devices.

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Self Synchronized Noise Systems:

Aug 03	Demonstrate capability to detect and process electromagnetic signals

Multifunction Imaging Microsystems:

Feb 03	Demonstrate 320 x 240 imaging with solid state radiation shield showing temperature reduction of 20K.
Mar 03	Demonstrate polarization sensitivity in an uncooled LWIR array.
Jun 03	Demonstrate mid wave room temperature array 320 x 240 with sensitivity suitable for imaging.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Command, Control and Communications Systems PE 0603760E, R-1 #48

COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	129.162	115.149	130.101	182.889	225.085	276.986	313.089	Continuing	Continuing
Command & Control Information Systems CCC-01	73.126	65.029	76.601	109.336	149.726	195.838	209.384	Continuing	Continuing
Information Integration Systems CCC-02	56.036	50.120	53.500	73.553	75.359	81.148	103.705	Continuing	Continuing

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

(U) This program element is budgeted in the Advanced Technology Development Budget Activity because its purpose is to demonstrate and evaluate advanced information systems research and development concepts.

(U) The goals in of the Command and Control Information Systems project are to develop and test innovative, secure architectures and tools to enhance information processing, dissemination and presentation capabilities for the commander. This will give the commander insight into the disposition of enemy and friendly forces, a joint situational awareness picture that will improve planning, decision-making and execution support capability, and provide secure multimedia information interfaces and assured software to "on the move users". Integration of collection management, planning and battlefield awareness programs is an essential element for achieving battlefield dominance through assured information systems. The project will also focus on information techniques to counter terrorism.

(U) The goals of the Information Integration Systems project are to take diverse data inputs from a variety of sources, efficiently disseminate the information, and perform distributed and dynamic all-source correlation and fusion to produce an integrated, geo-spatially referenced, battlefield database and knowledge-base. Through the use of wideband dissemination and integrated sensor management, the project will also facilitate multi-site, real-time, collaborative situation assessment and course-of-action evaluations. These goals are being addressed by the Dynamic Database (DDB) program, the Airborne Communications Node (ACN) program, the Command Post of the Future (CPOF) program, the Symbiotic Communications effort, the next Generation (XG) program and the Advanced Speech Encoding (Vocoder) program.

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(U) **Program Change Summary:** (*In Millions*)	**FY2001**	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	128.778	117.451	104.480
Current Budget	129.162	115.149	130.101

(U) Change Summary Explanation:

FY 2001	Increase reflects minor program repricing.
FY 2002	Decrease reflects minor program repricing.
FY 2003	Increase reflects the expansion of Network Surveillance and Attack Efforts, Project Genoa II and the Total Information Awareness program in project CCC-01.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Command & Control Information Systems CCC-01	73.126	65.029	76.601	109.336	149.726	195.838	209.384	Continuing	Continuing

(U) Mission Description:

(U) Military operations that have taken place since the end of the cold war have demonstrated that current theater command, control, communications, intelligence/information systems, and planning and rehearsal systems lack the ability to fully support operations in complex, time-critical environments. These operations range from conflict and peacekeeping in urban centers to heavy battle actions in remote areas. Current capabilities do not provide the commander with real time, secure, situational awareness nor the ability to orchestrate high-tempo planning, rehearsal and execution. The goals of the programs in this project are to develop and test innovative, secure architectures and tools to enhance information processing, dissemination and presentation capabilities for the commander. This will give the commander insight into the disposition of enemy and friendly forces, a joint situational awareness picture that will improve planning, decision-making and execution support capability, and provide secure multimedia information interfaces and assured software to "on the move users". Integration of collection management, planning and battlefield awareness programs is an essential element for achieving battlefield dominance through assured information systems.

(U) With the growing dependence on information systems and the pressing need to be able to get the right information to the right person at the right time, it becomes critical to deliver and protect information and assures the availability of associated services – particularly in a stressed environment. Ongoing information security programs funded in this project include the Information Assurance Science and Engineering Tools (IASET) program that is addressing the assurance problem by investigating the underlying science that would allow a formal understanding of the problem at hand, and the Organically Assured and Survivable Information Systems (OASIS) program. Two new efforts in this area are the Advanced Network Surveillance and Cyber Attack Data Correlation. Lastly, the Partners in Experimentation program that was previously funded in the Computing Systems and Communications Technology program element (PE 0602301E, project ST-24) transitions to this project in FY 2003.

(U) The Organically Assured and Survivable Information Systems (OASIS) program seeks to provide defense capabilities against sophisticated adversaries to allow sustained operation of mission critical functions in the face of known and future cyber attacks against DoD information systems. The technology development goals are to conceive, design, develop, implement, demonstrate and validate architectures, tools and techniques that would allow fielding of organically survivable systems. The hardest part of the problem is to provide a real-time capability to make trade-offs between security, performance and functionality of systems depending on the current situation. The approach of the program is to

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use a hierarchy of techniques that provide a layered defense. The program is researching intrusion tolerance techniques in three areas: Real-time execution monitors; error detection and tolerance triggers; and error compensation/response and recovery. Techniques are chosen for their security protection and balanced against the cost incurred in performance, functionality and affordability. OASIS is addressing techniques aimed at hardening servers, clients, and all their software against intrusions. Another major task the program is undertaking is to validate the effectiveness of the techniques and mechanisms developed. The challenge is to characterize the cost and benefits of the techniques sufficiently well to enable a rigorous systems engineering approach to the system design. The OASIS program will transition technologies that allow systems to continue to operate correctly in the face of successful intrusions and attacks through tolerance and self healing properties.

(U) The Advanced Network Surveillance program will develop technologies for monitoring activity on computer systems for signs of cyber attack, using a carefully designed mesh of detection methods and sources of data expanded significantly beyond operating system audits and network protocol logs. More comprehensive and accurate detection technologies will be developed as a result of systematic analysis of where manifestations of important classes of cyber attack can occur, development of sensors that use explicit knowledge of system functional behavior, and combining partial indications from different system layers. This area is critical in order to discover cyber attacks early enough and reliably enough to enable effective defensive actions to be taken before extensive damage is done to computerized systems and networks.

(U) The Cyber Attack Data Correlation program will develop technologies for dynamic deployment, coordination, protection, and correlation of cyber attack sensors to improve security of large networks against coordinated or strategic cyber attacks. Dynamic and distributed sensor techniques are critical to overcoming present and worsening problems with attacks that bypass static monitored network chokepoints, attacks that target the sensors themselves, and adapting sensors to increasing complexity and rates of change in the defended networks.

(U) The Partners in Experimentation program will conduct security technology experimentation with operational military and coalition partners. Operational experimentation will provide valuable feedback to the security technology research and development process which will demonstrate to operational personnel the benefits of advanced technology, and accelerate technology transition.

(U) The coming generation of collection systems will provide dramatically increased volumes of higher fidelity data to the operational decision-maker. The challenge will be to dynamically manage and synchronize this advanced collection architecture with the next-generation processing, exploitation and dissemination capabilities to provide the critical information to the decision maker in the constantly changing operational situation. The Advanced Intelligence, Surveillance and Reconnaissance Management (AIM) program will develop Collection Strategies and Multi-asset Synchronization components to dynamically optimize/synchronize, schedule, and task the spaceborne, airborne and ground based collection, processing, exploitation and dissemination architecture. The AIM program will optimize Intelligence, Surveillance and Reconnaissance

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(ISR) support to precision engagement and tactical operations by providing proactive information support to the warfighter, continuous integration of operations and ISR, responsive ISR timelines, optimal ISR confederation management, and synchronization of ISR asset and exploitation tasking. AIM will ensure near-real-time information support to commanders and the Joint Task Force by providing all echelons with: a common view of the collection environment; current status of collection, processing, exploitation and dissemination operations; faster than real-time modeling and simulation in support of trade-off decisions; and the ability to conduct real-time multi-echelon coordination and shared decision making. In addition, three new initiatives: Advanced Sensor/Strike Battle Manager, Advanced Ground Tactical Battle Manager, and Network Effects-based Targeting With Adversarial Reasoning (NETWAR) are funded in FY 2003.

(U) The objective of the new Advanced Sensor/Strike Battle Manager initiative is to assist warfighters planning complex campaigns with new air platforms that contain both precision sensors and precision weapons. It will combine symbolic reasoning about tactics and engagement options with numerical tools to optimize waypoints, schedule tasks, and dynamically synchronize multi-platform engagements.

(U) The objective of the new Advanced Ground Tactical Battle Manager initiative is to automatically extend operational plans sketched by commanders of robotic forces into commands for each tactical vehicle, taking into account terrain, restrictive rules of engagement, weather, and opponents' capabilities. It will construct contingency plans to anticipate uncertainties in opponents' location and capability, and dynamically replan operations as new information arrives.

(U) The objective of the new Network Effects-based Targeting With Adversarial Reasoning (NETWAR) initiative is to nominate critical targets in opponents' networks that achieve desired effects with minimal risk of collateral damage. It will model dependencies within and across networks, identify critical nodes, calculate potential work-around within and among networks to mitigate damage to those nodes, and recommend targets for precision engagement.

(U) The Control of Agent-Based Systems (CoABS) program is developing the ability to rapidly assemble a set of disparate information systems into a coherently interoperating whole. This is being done without redesigning legacy systems and includes interoperation with non-DOD governmental systems and open-sourced systems not built to a pre-existing government standard. The development and implementation of mobile agents and agent-communication languages will help both in the facilitation of multi-systems integration and in controlling the information flow to alleviate bandwidth saturation and degraded quality of service. The CoABS program will demonstrate and deploy a middleware-based approach, and toolkits for rapid creation of capability to support the interoperation of heterogeneous systems in contingency and coalition operations, and thus will enable the interaction of military and non-military resources in these critical operations.

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(U) Project Genoa is developing tools and a prototype infrastructure for collaborative crisis understanding and management for the national security community ranging from the National Command Authorities to Commanders of the Unified Commands. The growing transnational threats increase the need for early crisis discovery and mitigation. To develop timely preemptive or mitigating strategies, Project Genoa's objectives are to: (1) decrease the decision cycle time from days to hours by reducing the time it takes to go from problem detection to providing the decision maker with actionable options; (2) increase the number of situations that can be managed simultaneously by an order of magnitude; (3) decrease the reaction time when new information is received; and (4) reduce number of military deployments. The current clients for components of the prototype system are Joint Chiefs of Staff and Defense Intelligence Agency, National Security Agency, Office of Assistant Secretary of Defense (International Security Affairs), Joint Counter-intelligence Assessment Group, Commander-in-Chief Pacific (J3), and Commander Joint Forces Command (J9).

(U) Project Genoa II, part of the DARPA Total Information Awareness Program, will focus on the information technology support needed by teams of intelligence analysts and operations and policy personnel as they attempt to anticipate and preempt asymmetric threats to U.S. interests. Needed are faster systems of humans and machines, ways to overcome the biases and limitations of the human cognitive system, "cognitive amplifiers" that help teams of people rapidly and deeply understand complicated and uncertain situations, and methods to more effectively distribute data residing in break existing stovepiped information repositories. Genoa II will provide technologies to make the teams faster, smarter, and more collaborative. The project will apply automation to team processes so that more can be accomplished sooner. It will develop and deploy cognitive aids that allow humans and machines to think together about complicated problems, and it will override the barriers inherent in today's information stovepipes by creating a dynamic, adaptable, peer-to-peer collaborative environment that supports the necessary co-existence of hierarchical and network organizations. Genoa II's products will be deployed to the Information Awareness Center at U.S. Army INSCOM.

(U) The Total Information Awareness (TIA) program will focus on developing and implementing information technologies into a prototype system to aid in countering terrorism through prevention. The TIA program will predict and hence enable preemption of terrorist activity. TIA will: develop architectures for a large-scale counter-terrorism database, for system elements associated with database population, and for integrating algorithms and mixed-initiative analytical tools; develop novel methods for populating the database from existing sources, create innovative new sources, and invent new algorithms for mining, combining, and refining information for subsequent inclusion into the database; and, develop revolutionary new models, algorithms, methods, tools, and techniques for analyzing and correlating information in the database to derive actionable intelligence. DARPA will work in close collaboration with one or more U.S. intelligence agencies that will provide operational guidance and evaluation, and act as a technology maturation and transition partner(s). The TIA focus is on developing usable tools, rather than conducting demonstrations. That is, creating fully functional, leave-behind prototypes that are reliable, easy to install, and packaged with documentation and source code (though not necessarily complete in terms of desired features), that will enable the intelligence community to evaluate new technology

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through experimentation, and rapidly transition it to operational use, as appropriate. The primary goal of TIA is the assured transition of a system-level prototype that integrates technology and components developed in other DARPA programs including Genoa and Genoa II described above; TIDES (PE 0602301E, ST-11); Genisys, EELD, WAE, HID, and Bio-Surveillance described in PE 0602301E, ST-28.

(U) The Active Templates (AcT) program will produce a robust, lightweight software technology for aiding in the automation of detailed planning and execution for military operations using a plan spreadsheet metaphor. Active Templates are distributed data structures whose variables will be linked to live data feeds or problem-solving methods. AcT will assist with automated planning and execution by capturing, improving and updating critical information such as current state, goals, constraints, alternative actions, standard defaults, decisions in context and rationale. Active Templates will be designed to be user-tailorable, networked, noise-tolerant, user-supported, scalable, and widely adopted. As a result, the technology to be fielded will provide faster plan generation (six times), improved plan quality (eight times more options considered), 60 percent reduction in staff-hours required to track and coordinate missions, enhanced ability to capture lessons learned, and improved national capability to respond in a crisis. Early prototypes of AcT technologies have been adopted by Special Operations Command where they have been shown to accelerate temporal planning by a factor of four and reduce the number of personnel required for battle tracking by a factor of six. DARPA is working closely with the Joint Special Operations Command to add spatial planning capabilities and simple forms-based coordination tools that may be defined dynamically by ordinary users in less than a day. Experiments (e.g., time-and-motion studies) with these technologies show improvements in the range indicated above.

(U) The Tera Hertz Operational Reachback (THOR) program will mature required technologies and credibly demonstrate a system able to provide a high data rate (internet-like) backbone to the tactical user whether airborne, terrestrial, or maritime. By focusing on the militarily unique need for a truly mobile and deployable high-data-rate infrastructure that extends access to existing commercial and military terrestrial fiber infrastructures, the Department's vision of a "Global Grid" will be enabled by creating the high-data-rate nexus among the terrestrial, space, and air grids. This is expected to be accomplished by leveraging the commercial global optical fiber network, multi-quantum well retro-reflectors, and advances in optical phased array technology that have been motivated by directed energy applications. Together, these technologies enable the creation of a hybrid fiber-free space optical network extension. Gigabit-per-second connectivity and long-haul reachback to and between airborne assets, as well as multi megabit-per-second connectivity and reachback to and from terrestrial and maritime forces will be demonstrated in the final year of the program.

(U) The Joint Force Air Component Commander (JFACC) program has addressed critical issues in military command and control (C2), specifically joint and coalition air operations by developing and validating new C2 architectural concepts and appropriate control strategies. Final demonstrations and evaluations complete in FY 2001.

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(U) Building upon the results of previous C2 efforts, the Man and Machine Command and Control (M2C2) program developed the theory, algorithms, software, modeling and simulation capabilities to coordinate multi-level planning, assessment and control of distributed semi-autonomous forces with collective objectives through the hierarchical application of systems and control theoretic methods.

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

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

- Man and Machine Command and Control (M2C2). ($10.458 Million)
  - Developed theories for resource allocation and task negotiation.
  - Cultivated control technologies for optimal route planning to fixed/mobile targets.
  - Developed estimation techniques to reconstruct decision information in the presence of measurable feedback.
  - Created designs for hierarchical decision-making tools within a dynamic, closed-loop architecture.

- Joint Forces Air Component Commander (JFACC). ($7.000 Million)
  - Completed experimentation and evaluated effectiveness of C2 architectures incorporated, via simulation, into air operations systems.

- Information Assurance Science and Engineering Tools (IASET). ($20.209 Million)
  - Developed initial science-based security enabling disciplines, methods, and preliminary tools that will allow for the design of measurable and useful Information Assurance systems. These deliverables will be provided to the ULTRA*LOG, OASIS, FTN and Cyber Panel programs.
  - Demonstrated real-time execution monitoring techniques and tools to mitigate malicious mobile code.
  - Demonstrated integrity mark technology for protection of sensitive imagery.
  - Investigated new approaches to intrusion tolerance based on data, spatial, temporal and analytical redundancy and resource allocation; identified relevant challenge problems.
  - Demonstrated self-protecting mobile agent prototype.
  - Developed architecture for building intrusion tolerant systems from potentially vulnerable components by applying existing fault-tolerant approaches to intrusion tolerance and that support layered defenses and provide resilience to attacks.

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- Advanced ISR (Intelligence, Surveillance and Reconnaissance) Management (AIM). ($6.800 Million)
  - Explored new ISR system architectures and technologies to increase effectiveness and reduce man loading in tactical as well as planning applications.
  - Conducted operational evaluation of AIM automated collection Strategy Developer (SD) and Multi-Asset Synchronizer (MAS) technologies with U.S. Southern Command. Employed MAS as an off-line, real-time, component of operational exercise Unified Endeavor 2001/2003.
  - Expanded SD and MAS capabilities to include tasking of and Signal Intelligence sensors. Characterized performance of AIM components in terms of algorithm timeliness and quantitative collection needs derived from real time processing and exploitation systems such as Dynamic Database (DDB).
  - Evaluated dynamic re-planning capabilities as part of an integrated collection management demonstration linking AIM and Dynamic Database technologies in a novel control paradigm that enables responsive sensor management driven by data exploitation needs.
  - Established a collaborative engineering environment to conduct AIM/DDB experimentation. Knowledge gained in these experiments transitioned to the Dynamic Tactical Targeting (DTT) program in FY 2002.
  - Partnered with the DIA Joint Intelligence Virtual Architecture program to explore use of their Joint Collaborative Environment as an application server for making AIM components more broadly and rapidly accessible to operational users.
  - Experimented with NRO to introduce AIM technologies to their advanced concept development environment.

- Control of Agent-Based Systems (CoABS). ($11.745 Million)
  - Demonstrated a CoABS Grid that was self-healing, operating without human intervention, quickly assembled, supporting 100's of sensors in a heterogeneous environment.
  - Demonstrated mobile agents and tools that are capable of significantly reducing bandwidth demands (>65%); and capable of going anywhere, anytime, autonomously to gather data or perform other functions.
  - Empirically demonstrated efficacy of approach in realistic military domains, such as Fleet Battle Experiments.

- Active Templates. ($9.408 Million)
  - Integrated and demonstrated multiple templates merging by users to update information, add dependencies and attach problem-solvers.

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- Demonstrated initial capability to automatically and continuously compile geophysical information from different databases and other networked information sources.

- Project Genoa. ($7.506 Million)
  - Completed development of corporate memory, future scenario generation tools and tailored presentation tools.
  - Developed and validated emerging concepts from collective reasoning applied to the asymmetric threat.
  - Investigated the use of intelligent agents to automate functions where possible.
  - Incorporated changes resulting from client evaluation in real world asymmetric environment.

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

- Advanced ISR (Intelligence, Surveillance and Reconnaissance) Management (AIM). ($11.110 Million)
  - Evaluate integrated AIM capabilities for optimized ISR collection management to provide continuous dynamic and proactive collaboration between operations and ISR.
  - Develop user interface to include task valuation and prioritization methodologies and associated metrics in combination with quantitative data driven needs, for use in multi-user/multi-mission environments.
  - Complete experimentation/validation of AIM technology in a major military command environment with participation in a command level exercise such as millennium challenge 02 or Joint Expeditionary Force Experiment (JEFX).
  - Conduct final year assessment and evaluation for military utility, and transition of Multi-Asset Synchronizer and Strategy Developer tools to airborne and overhead collection systems including collection management migration systems, IC MAP.
  - Develop "front-end" input through use of AIM Market Oriented Prioritization (AMOP) approach.
  - Utilize "Knowledge Capture" techniques to assess program maturity and define future applications/experimentation and transition opportunities.

- Control of Agent-Based Systems (CoABS). ($11.110 Million)
  - Release Agent-Grid code and components tailored to military user needs, with automated features for rapid (<hours) grid creation.
  - Demonstrate the scalability of the architecture to support > 1,000 agents without conflicts.
  - Evaluate CoABS in military applications including major joint exercises featuring coalition operations and situation.

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- Active Templates. ($11.018 Million)
  - Develop Active Template representation/library capabilities for extending the terms, critical planning parameters for template adaptation and merging.
  - Demonstrate advanced tools for extending term-ontology to avoid duplication and conflicting semantics.

- Project Genoa. ($7.639 Million)
  - Continue testing and experiments in user environments.
  - Modify Genoa infrastructure as needed in user environments.
  - Transition components to user agencies such as Joint Chiefs of Staff, Defense Intelligence Agency, OSD(C3I), OSD(ISA), etc.
  - Deploy and support leave-behind prototypes at critical nodes within the intelligence community for use during Operation Enduring Freedom and the continuing war on terrorism.
  - Create an on-site laboratory at an intelligence agency for rapid prototyping and testing new ideas for follow-on Genoa programs.

- Organically Assured and Survivable Information Systems (OASIS). ($18.152 Million)
  - Develop an experimental intrusion tolerant database from commercial-off-the-shelf (COTS) components.
  - Begin development of a system for automated behavior modeling of programs and information systems.
  - Explore design of intelligent systems that can judge the trustworthiness of their computational environment and make strategy and resource allocation decisions.
  - Design a framework for tolerating intrusions in large-scale, heterogeneous, networked computing enterprises.
  - Develop algorithms that tolerate random, unpredictable (Byzantine) faults resulting from a class of staged, coordinated intrusions.
  - Demonstrate a scalable intrusion-tolerant architecture for distributed services prototype.
  - Explore the best approach to development of a self-healing system.
  - Integrate OASIS technologies to demonstrate a notional intrusion tolerant architecture.
  - Prototype new cyber attack detection techniques that use application, operating system, or network data not captured in operating system audit or network packet logs.

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- Develop taxonomic models of attack methods and manifestations and use them to expose gaps in detection.
- Initiate development of capabilities for deploying, retargeting, and analyzing placement of cyber attack detection sensors in a large network.

• Tera Hertz Operational Reachback (THOR). ($6.000 Million)
- Initiate development of a high power laser source by phase combining multiple inexpensive lasers used by the telecommunications industry.
- Demonstrate eight milli-watt fiber laser phasing with an overall output equal to the number of fibers times their individual output power.
- Initiate development of a passive optical terminal.
- Demonstrate quantum well modulating corner cube retro reflector operation at 1.55 μm wavelength in the laboratory.
- Investigate the use of steerable agile beam technology to eliminate the gimbals.

(U) <u>FY 2003 Plans:</u>

• Active Templates. ($5.175 Million)
- Develop Active Template Planning and Execution Shell including tools for template development such as selecting and tailoring dependencies and problem solving algorithms. These tools will also include advanced problem solvers like generative planning, temporal/uncertain reasoning and triggering for complex events.

• Organically Assured and Survivable Information Systems (OASIS). ($6.812 Million)
- Demonstrate a comprehensive approach to intrusion tolerance in a commercial-off-the-shelf (COTS) setting.
- Prototype and evaluate a framework for tolerating intrusions in large-scale, heterogeneous, networked computing enterprises.
- Build a distributed compositional architecture for the deployment of intrusion tolerance mechanisms implementing an explicitly stated but flexible tolerance policy.
- Develop an integrity and availability framework that combines passive intrusion tolerance and active intrusion recovery mechanisms.

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- Advanced Network Surveillance. ($7.500 Million)
  - Research the theoretic aspects of dynamic security models and formal assurance modeling necessary to improve the ability to make quantitative assessments of the assurance of information systems and networks.
  - Develop models for the hierarchical diffusion of fault adaptive methods through the physical, component, system, and mission levels of a distributed system architecture.

- Cyber Attack Data Correlation. ($9.000 Million)
  - Develop sensor protection and peer-challenge techniques to discover sensors that have been subverted or lost to attacks.
  - Develop techniques for communicating cyber attack detection data among a dynamic collection of cyber attack detection sensors.
  - Investigate new system enforcement and response mechanisms that can actively aid with cyber attack detection.

- Partners in Experimentation. ($3.044 Million)
  - Demonstrate large-scale hardened client technology and policy implementation in military operational environment.
  - Evaluate performance and scalability of lab proven anomaly detection techniques for intrusion detection in real world high volume environments.

- Tera Hertz Operational Reachback (THOR). ($11.000 Million)
  - Complete system trade studies for a maritime terminal.
  - Extend the advantages of High Data Rate fiber to the mobile expeditionary warfighter whether on land, on the sea, or under the sea.
  - Provide free space optical connectivity from a terrestrial Point of Presence into the theater of operations via air relay.
  - Provide large reductions in size, weight, and prime power consumption over state of the art systems.
  - Provide significant cost reduction in optical links.
  - Demonstrate end-to-end system concept for the warfighter.

- Control of Agent-Based Systems (CoABS). ($2.070 Million)
  - Expand the capability of the Grid and Agent systems to support inclusion of National Sensors and additional data fusion functions.
  - Develop an experimentation project to infuse innovative and transformational concepts and technology for Navy Expeditionary Sensor Grid.

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- Project Genoa II. ($7.000 Million)
  - Design faster systems of humans and machines by assimilating new information technologies to operational agencies to meet asymmetric threats.
  - Develop tools for cognitive amplification by extending the ability of software to model current states, estimate plausible futures, support formal risk analysis, and provide for automated option planning. Supporting technology includes the use of intelligent agents, cognitive machine intelligence, associative memory, neural networks, pattern matching, Bayesian inference networks, and biologically inspired algorithms.
  - Develop tools for cross-agency collaboration designed to operate across existing hierarchical organizations while maintaining control and accountability. Areas under consideration will include: Knowledge Management; corporate memory; context-driven, declarative-policy enforcement; self-aware data; business rules; self-governance; and automated planning.

- Total Information Awareness (TIA). ($10.000 Million)
  - Initiate development of architectures for large-scale counter-terrorism database.
  - Develop novel methods for populating database from existing sources.
  - Develop new models, algorithms, methods, tools and techniques for analyzing and correlating information in the database.

- Advanced Sensor/Strike Battle Manager. ($5.000 Million)
  - Build models, plan authoring tools, and planning algorithms to plan strike missions using air platforms carrying both sensors and strike weapons.
  - Incorporate a capability to manage shoot-look-shoot engagement strategies supported by multiple platforms.

- Advanced Ground Tactical Battle Manager. ($5.000 Million)
  - Build situation estimation, situation assessment, and tactical plan generation tools to generate and update, continuously, plans for tactical ground combat.
  - Incorporate a capability to create and modify new tactics in response to evolving enemy capabilities and differing operational environments.

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- Network Effects-based Targeting With Adversarial Reasoning. ($5.000 Million)
  - Build models, analysis tools, and plan generation tools to identify critical nodes in opponents' networked systems, both military (e.g., logistics) and dual use (e.g., transportation).
  - Incorporate a capability to anticipate opponents' workarounds to U.S. attacks, including repair, reconstitution, or substitution.

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

- Not Applicable.

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

<u>Plan</u>	<u>Milestones</u>
Advanced ISR (Intelligence, Surveillance and Reconaissance) Management (AIM):	
Mar 02	Test and evaluate open and closed loop performance of AIM system to coordinate ISR collection assets in a dynamic and responsive multi-user environment.
Jul 02	Conduct experimentation of AIM technology at operational command (e.g. Joint Battle Center (JBC), USSOCOM, CENTCOM).
Sep 02	Transition AIM technology to collection management systems (e.g. IC MAP, DCGS, CICMP).
Control of Agent-Based Systems (CoABS):	
Jul 03	Release product quality Agent Grid code, generalized for broad military users and commercial standards group.

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Active Templates:

Sep 02	Show six-fold increase in execution replanning using Active Templates attached to live data feeds from battlefield sensors. Active Templates command and control tools were used for special operations forces contingency planning in support of Operation Enduring Freedom.
Sep 03	Demonstrate capability for distributed battlestaffs to tailor templates, six times faster plann generation, eight times more options, availability of 500 Active Templates and 60 percent reduction in staff-hours required to track/coordinate missions.

Tera Hertz Operational Reachback (THOR):

Apr 02	Technology tasks contract award.
Apr 02	System integrator contract award.
Dec 02	Solicitation for critical subsystem bb/bb prototyping & technology demonstrations.
Feb 03	Critical subsystem contract award..

Organically Assured and Survivable Information systems (OASIS):

Aug 03	Integrated Design and Assessment Environment applied to design effort for new information system.
Oct 03	Conduct empirical validation experiments of mathematical computation models that include code mobility.

Partners in Experimentation:

Sep 03	Complete large scale hardened client and server experiment as well as Perpetually Available and Secure Information Systems (PASIS) and email sandboxing experiments in operational environments.

Advanced Network Surveillance:

Sep 03	Complete first design iteration of fault adaptive distributed system architecture.

Cyber Attack Data Correlation:

Sep 03	Conduct preliminary experiments validating the utility of system enforcement and response mechanism prototypes.

Project Genoa:

Aug 02	Create On-site laboratory for rapid prototyping and testing.

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Project Genoa II:
Sept 03 Develop tools for cognitive amplification and cross-agency collaboration.

Total Information Awareness (TIA):
Sep 03 Develop architectures, new models and tools for analyzing and correlating database information.

Advanced Sensor/Strike Battle Manager:
Mar 03 Complete system functional architecture and baseline technology prototypes for critical functions.

Advanced Ground Tactical Battle Manager:
Sep 03 Conduct initial demonstration in an instrumented experimentation facility.

Network Effects-Based Targeting with Adversarial Reasoning:
Sep 03 Assess baseline technologies on network model simulations with 100-node networks.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Information Integration Systems CCC-02	56.036	50.120	53.500	73.553	75.359	81.148	103.705	Continuing	Continuing

(U) Mission Description:

(U) The goals of the Information Integration Systems project are to take diverse data inputs from a variety of sources, efficiently disseminate the information, and perform distributed and dynamic all-source correlation and fusion to produce an integrated, geo-spatially referenced, battlefield database and knowledge-base. Through the use of wideband dissemination and integrated sensor management, the project will also facilitate multi-site, real-time, collaborative situation assessment and course-of-action evaluations. These goals are being addressed by the Dynamic Database (DDB) program, the Airborne Communications Node (ACN) program, the Command Post of the Future (CPOF) program, the Symbiotic Communications effort, the next Generation (XG) program, and the Advanced Speech Encoding (Vocoder) program.

(U) The overarching goal of the Dynamic Database (DDB) program was to continuously produce significant battlespace information from immense quantities of multi-sensor data in a manner responsive to tactical users at multiple echelons. More specifically, DDB ingests and registers Ground Moving Target Indicator radar, Signals Intelligence and Imagery (Synthetic Aperture Radar, Electro-Optic and Infra-Red) Intelligence raw sensor data to a common fiducial to reference all sensor data to a Common Targeting Grid. DDB components have been integrated with components of the Advanced Intelligence, Surveillance and Reconnaissance Management (AIM) program to develop a control theoretic framework for sensor management and data exploitation. The coupling of these technologies will demonstrate a proof of concept in which additional data required by DDB processes is used to drive sensor collections. The DDB program concluded in 2001 and the technology demonstrated, to include the DDB-AIM experiment, provided the underpinnings of the Dynamic Tactical Targeting (DTT) program that is beginning in FY 2002 (PE 0603762E, Project SGT-04, Sensors and Exploitation Systems).

(U) The Airborne Communications Node (ACN) program will enable an affordable, autonomous communications infrastructure that simultaneously provides assured communications, situational awareness and signals intelligence (SIGINT). It is envisioned that ACN payloads will be integrated on platforms ranging from High Altitude Endurance (HAE) unmanned airborne platforms (e.g., Global Hawk) to tactical platforms (e.g., Predator, Army Tactical UAV). The ACN payload will be scalable such that payloads for various platforms can be constructed from a core module set. The ACN on a HAE will provide wide-area wireless communications and SIGINT services over the theater of operation for joint and multinational forces by establishing an early robust airborne infrastructure for intra-theater line-of-site (LOS) and reachback beyond line-of-site

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(BLOS) without the need for large in-theater assets. ACN will augment and enhance the battlefield communications infrastructure in order to adapt communications, situational awareness and SIGINT services to the flow of battle. Therefore, the ACN system needs to be adaptable, interoperable, robust, secure, and affordable within the size, weight and power constraints of the intended platforms.

(U) In current tactical operations, ground commanders conduct operations with a situational awareness that measures around 27 percent to 50 percent of ground truth. This uncertainty, often called the 'fog of war', slows down and degrades the quality of command decisions. Radical improvements in situational awareness are necessary for effective tactical operations. The objective of the Command Post of the Future (CPOF) program is to improve the speed and quality of command decisions, more effectively disseminate command decisions, and reduce the number of staff members required to process and manage the information systems. Three important command functions will be addressed to achieve this objective: 1) improved speed and quality of situation awareness; 2) improved speed of course of action (COA) development and selection; and 3) improved clarity of COA communication between commander and subordinates. For each of these command functions, CPOF is developing technologies that leverage the expertise of the commander by exploiting and augmenting natural cognitive abilities. The key technologies to be developed are: (1) an integrated visualization environment for the commander and his staff; (2) a powerful and comprehensive human-computer interaction capability; (3) a robust collaborative communication environment for creating shared understanding among commanders and staff through both voice and visual interactions; (4) an integrated suite of systems to automate many of the lower level staff functions and automatically invoke and operate supporting, planning and analysis applications; and (5) a modular, portable suite of software components that can be quickly configured and tailored to various command environments (stationary and mobile), at different echelons of tactical command. The program concludes at the end of FY 2002.

(U) Future combat systems increasingly rely on accurate intelligence preparation of the battlefield. This includes timely and accurate georegistration of all sensed data for precision weaponry on targets (including mobile targets). The single biggest error source that exists in the georegistration process is the lack of accurate knowledge of the terrain. Current national databases provide only coarse Level 1 data and in a few years Level 2 data will become available. This is insufficient to take full benefit of even current generation weapon accuracies and will continue to fall further behind as the weapons navigation and guidance systems improve at a faster pace. In order to overcome this, the Symbiotic Communications program will develop an airborne system that can generate, in real-time, Digital Terrain Elevation Data (DTED) with a precision commensurate with NIMA defined Level 4. This system will operate in all weather and passively. An additional attribute being explored includes automated terrain categorization that can delineate degrees of wetness and discriminate between fields and trees. In addition, exploration of techniques for using multiple frequencies to achieve enhanced spatial resolution leading to a potential DTED Level 5 precision will be conducted.

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(U) The Next Generation (XG*)* program goals are to develop both the enabling technologies and system concepts to provide dramatic improvements in assured military communications in support of a full range of worldwide deployments through the dynamic redistribution of allocated spectrum along with novel waveforms. U.S. Forces face unique spectrum access issues in each country in which they operate, due to competing civilian or government users of national spectrum. These constraints must be reflected in all force planning and may preclude operation of critical systems. Coalition and allied operations are even more complex to manage, and may severely limit the U.S. ability to fully exploit its superiority and investment in information technology. The XG program approach is to develop the theoretical underpinnings for dynamic control of the spectrum, the technologies and subsystems that enable reallocation of the spectrum, and the system appliqué prototypes to demonstrate applicability to legacy and future DoD radio frequency emitters. The approach plans to investigate methods to leverage the technology base in microelectronics with new waveform and Medium Access and Control protocol technologies to construct an integrated system. The proposed program goals are to develop, integrate, and evaluate the technology to enable equipment to automatically select spectrum and operating modes to both minimize disruption of existing users, and to ensure operation of U.S. Systems. The result of the XG program will be to develop and demonstrate an appliqué for legacy and future emitter systems for joint service utility.

(U) The Advanced Speech Encoding (Vocoder) program will investigate the reduction of voice communication bit rates. The program will compress speech to bit rates between 200 bps and 800 bps while producing speech quality at least as good as that produced by the current standard, and maintaining that quality and bit rate in militarily relevant noisy environments. Reliable authentication of the speaker’s identity will also be investigated. This will be accomplished by directly measuring the glottal excitation function, which, when combined with the information contained in the acoustic data, allows direct computation of the physical vocal tract transfer function. Furthermore, since the physical vocal tract transfer function is directly associated with the formation of phonemes, it is possible to recognize the phonemic information in the speech and transmit that thus allowing further data rate reductions. Finally, direct measurement of the vocal excitation waveform potentially provides a unique physiological set of metrics that can be used for speaker authentication.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

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- Dynamic Database (DDB). ($6.340 Million)
  - Completed development of registration algorithms to co-register Ground Moving Target Indicator (GMTI), Signals Intelligence (SIGINT), and Imagery Intelligence (IMINT) data to a standard National Imagery and Mapping Agency (NIMA) terrain product - Common Image Base (CIB).
  - Completed algorithm development to use nonlinear techniques for automatic recognition of speakers and parameter characterization of emitters, derivation of tactical communications networks from communications emissions, recognition of new/different vehicular behavior from GMTI and near real time extraction of military objects from multi-spectral imagery.
  - Completed initial capability for object discovery of large numbers of tactically significant ground targets (moving and stationary) over a brigade size area.
  - Demonstrated an initial capability to derive force relationships among objects using the Force Level Change Detection (FLCD) algorithm.
  - Demonstrated an interactive DDB system-level capability that performs multi-sensor object level fusion using a Kosovo-like data set.
  - Conducted proof of concept experiments integrating components of DDB and AIM technology in a control theoretic framework.

- Command Post of the Future (CPOF). ($17.861 Million)
  - Continued to develop and integrate new CPOF technology into a complete CPOF commander's dialog system to enable commanders to improve the speed and quality of command decisions to stay ahead of the adversary's ability to react.
  - Integrated and tested new versions of the technology components in a series of simulation-based decision experiments.
  - Integrated the most effective technology into a complete CPOF commander's dialog system for an end-to-end demonstration in a simulated joint exercise.
  - Began preparations for an operational demonstration of the CPOF commander's dialog system in a joint field exercise in FY 2002.

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- Airborne Communications Node (ACN). ($31.835 Million)
  - Demonstrated performance of critical technologies (co-site mitigation, antennas, array processing, power amplifiers, multi-band coupler, mobile ad hoc networking).
  - Matured the ACN system architecture and developed point designs for multiple platforms (Global Hawk, Predator, and Shadow 200).
  - Demonstrated feasibility of multi-mission concept (simultaneous support of communications and SIGINT) through detailed system simulation.
  - Initiated a study to examine integration of FCS high band communications, directional networking, and Small Unit Operations/Situational Awareness System (SUO SAS) waveform integration within the ACN architecture.

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

- Airborne Communications Node (ACN). ($16.048 Million)
  - Verify the system design through simulation and end-to-end laboratory demonstration.
  - Mature the architecture to a critical design.
  - Commence transition of system to Services.
  - Continue/complete technology development.
  - Complete study examining integration of FCS high band communications, directional networking, and SUO SAS waveform integration within the ACN architecture.

- Symbiotic Communications. ($21.396 Million)
  - Complete ground experiments for signal and terrain scatter characterization.
  - Complete initial development of range compression algorithms.
  - Complete preliminary system analyses and trade studies.
  - Initiate planning and hardware development for early flight test.
  - Initiate development of data processing architecture and algorithms.
  - Investigate terrain classification using polarization, spatial and spectral diversity.
  - Investigate high-resolution passive imaging of emitters.
  - Investigate potential platforms and begin hardware optimization process.

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- Command Post of the Future (CPOF). ($4.676 Million)
  - Complete the final experiments in cognitive principals of visualization, multi-modal interaction, collaborative planning and command decision-making.
  - Complete technology development of CPOF component technologies of dynamic visualization, multi-modal interfaces and collaborative planning.
  - Integrate final component technologies and knowledge bases into the final prototype commander's mobile interactive display system, the BattleBoard; qualify system capabilities.
  - Participate in an advanced warfighting experiment using the CPOF BattleBoard as the primary command interface of the brigade and battalion level.
  - Transition and integrate the CPOF commander's dialog system into the Army's Agile Commander ATD testbed.

- Next Generation (XG). ($4.000 Million)
  - Initiate CONUS and OCONUS Spectrum Usage Analysis.
    -- Military bands during Force Exercises.
    -- Civilian band usage in a variety of locales (urban and rural settings).
  - Award initial technology and system contracts.
  - Investigate the higher-level functions required for multi-requirement optimization and parameterization of a waveform to include processing load, timing & synchronization.
  - Investigate concepts for employment and utility of a dynamic waveform to the warfighter.

- Advanced Speech Encoding (Vocoder). ($4.000 Million)
  - Begin development of noise suppression algorithms.
  - Begin development of speaker authentication features and algorithms.
  - Begin development of less than one KB per second vocoder.

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(U) **FY 2003 Plans:**

- Airborne Communications Node (ACN). ($11.500 Million)
  - Mature technology to technology readiness level (TRL) 5 by mid FY 2003.
  - Complete transition of system into Services.
  - Down-select to one contractor team, based on the results of the end-FY02 laboratory demonstration, to go forward into prototype and flight demonstration.
  - Initiate a joint-funded (Service(s) and DARPA) effort to prototype multi-mission ACN payload flight hardware and integrate on a manned aircraft for flight demonstrations and exercise participation.
  - Continue development of technologies to reduce overall size, weight, and power to support eventual integration (post initial flight demonstration) on strategic (Global Hawk) and tactical (Shadow) UAVs.
  - Participate in Joint Forces Command exercise.
  - Continue focused development of antennas to support aircraft integration.

- Symbiotic Communications. ($25.000 Million)
  - Complete development of data processing architecture and algorithms for non-real time system.
  - Conduct flight tests with non-real time system to validate algorithms.
  - Demonstrate Digital Terrain Elevation Data (DTED) 3 with non-real-time processing of flight data.
  - Conduct critical design review for real-time airborne system.
  - Initiate development of real-time airborne system.

- Next Generation (XG). ($10.000 Million)
  - Complete spectrum analysis of military bands usage.
    -- Conduct two to three exercises at 10 plus locations.
    -- Establish baseline for analysis.
  - Conduct Lab Demo of Sense and Adaptation Technology Performance.
    -- Perform analysis and simulation of multiple control protocols.
    -- Use military band spectrum analysis to assess subsystem technology development.

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- Identify attacks of concern against various items, including; software radios, beam-forming antennae, and 3G handsets.
- Quantify differential between linear multistage transforms and linear with one non-linear stage transform.
- Initiate development of testbed for hardware in-the-loop testing of concepts.
- Characterize next generation Electronic ally Steerable Array antenna, and Rf component technology for inclusion into eventual demonstrator.

• Advanced Speech Encoding (Vocoder). ($7.000 Million)
  - Complete development of noise suppression algorithms.
  - Demonstrate <1 kb/sec vocoder.
  - Begin development of prototype chip combining vocal waveform measurement radar and associated software.

(U) Other Program Funding Summary Cost:

• Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Airborne Communications Node:	
Jan 02	System design review incorporating integration plan and physical architecture allocation.
Sep 02	Critical Design Review and Technology Rediness Level 5 laboratory demonstration.
Symbiotic Communications:	
May 02	Complete terrain scatter studies.
Jun 02	Demonstrate range compression processing.
Apr 03	Complete early flight test.
Jun 03	Demonstrate SAR and digital terrain elevation data level three processing.
Aug 03	Preliminary Design Review for airborne system.

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Next Generation (XG):

Apr 02	Initial system design, sensing, dynamic waveform, sense and adapt technology devebpment contract awards.
Aug 02	Analyze and measure spectrum usage in urban, open and forested environments.

Advanced Speech Encoding (Vocoder):

Mar 02	Performer contract awards.
Sep 02	Complete development of noise suppression algorithms.
Sep 03	Demonstrate less than one kb per second vocoder.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	138.508	192.095	224.000	216.840	200.430	200.191	200.742	Continuing	Continuing
Guidance Technology SGT-01	20.212	37.401	44.000	48.704	54.536	56.407	65.186	Continuing	Continuing
Aerospace Surveillance Technology SGT-02	23.142	23.732	28.000	24.849	24.789	24.792	19.753	Continuing	Continuing
Air Defense Initiative SGT-03	21.236	24.155	31.000	37.770	30.738	28.792	24.938	Continuing	Continuing
Sensors and Exploitation Systems SGT-04	73.918	106.807	121.000	105.517	90.367	90.200	90.865	Continuing	Continuing

(U) **Mission Description:**

(U) The Sensors and Guidance Technology program element is budgeted in the Advanced Technology Development Budget Activity because it is developing the system oriented technologies necessary to enhance sensor and weapon system accuracy and capability to meet current and emerging threats. Four projects are funded in this program element: Guidance Technology, Aerospace Surveillance Technology, the Air Defense Initiative, and Sensors and Exploitation Systems.

(U) The Guidance Technology project is leveraging geolocation technologies to enhance the navigation and/or guidance packages of airborne platforms, ground vehicles and weapons. These improved systems will improve the accuracy and effectiveness of stand-off weapons, minimizing collateral damage while reducing the cost-per-kill.

(U) Aerospace Surveillance Technology programs are developing technologies to improve the accuracy and timeliness of surveillance systems in all weather, in hostile reception environments, and when necessary, in a covert manner. The programs funded by this project exploit recent advances in multispectral target phenomenology, signal processing, lower power high performance computing and low cost microelectronics technologies.

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(U) The Air Defense Initiative is an on-going project whose overall goal is to counter advanced battlefield threats and enhance the survivability of U.S. assets in the face of enemy electronic countermeasures.

(U) The objective of the Sensors and Exploitation Systems project is to provide the warfighter with situational awareness and battlefield dominance by developing key sensor technologies; providing near-real-time semi-automatic exploitation of wide-area moderate (and high) resolution imagery data; providing real-time and accurate battlefield assessment; and robust, precise and reliable identification, precision fire control tracking and engagement of high value units and critical moving targets.

(U) **Program Change Summary:** (*In Millions*)	**FY2001**	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	139.858	203.095	178.715
Current Budget	138.508	192.095	224.000

(U) **Change Summary Explanation:**

FY 2001	Decrease reflects the SBIR reprogramming and minor program realignments.
FY 2002	Decrease reflects congressional program reduction partially offset by the Large Millimeter Wavelength Telescope congressional add.
FY 2003	Increase reflects increased Agency emphasis on precision weapon targeting and tracking, and expanded funding for sensor data exploitation.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Guidance Technology SGT-01	20.212	37.401	44.000	48.704	54.536	56.407	65.186	Continuing	Continuing

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

(U) Fire-and-forget standoff weapons need precise targeting information if critical fixed and mobile targets are to be eliminated effectively with minimal collateral damage and minimum cost-per-kill. This requires that: (1) military surveillance and targeting systems geolocate targets accurately in the same coordinate system in which the weapon system navigates; (2) the surveillance, targeting and weapon systems have precision navigation and guidance systems on-board; and (3) navigation and target location systems robustly operate day/night and in adverse weather. In addition, future systems designed to accomplish precision strike missions must be significantly more affordable. The achievement of these characteristics in an integrated system is the goal of this program. Thrusts are included in this project to increase the ability of Global Positioning System (GPS) users to operate effectively in presence of enemy jamming; to increase the versatility of navigation systems applications by developing micro electromechanical sensor inertial navigation system technologies; and to apply the geolocation technologies/techniques to precision threat geolocation of short-dwell emitters or passive air defense systems.

(U) The Global Positioning Experiments (GPX) program will increase the ability of GPS users to operate effectively in the presence of enemy jamming or countermeasures. It will demonstrate feasibility of airborne pseudolite (APL) concepts, which would sustain the availability of GPS signals to users in the presence of enemy jamming. The considerably increased transmit power of the APL fights off the effects of jamming on DoD receivers. APLs can be rapidly deployed on unmanned aerial vehicles (or other airborne platforms) and provide theater-wide coverage for individual soldiers, combat platforms and precision GPS-guided shoot-to-coordinate weapons. The program addresses three key challenges. First, it demonstrates non-Keplerian orbit predictions of the APL and shows that only software modifications are needed for GPS user receivers. Second, the APL must also accurately navigate using GPS satellites in the presence of jamming. Accordingly, this program provides for the design, development and demonstration of a low cost, space-time adaptive beamforming anti-jam receive antenna and a digital adaptive beamformer. With advanced algorithms, this will support greater than 45 dB nulls against up to six different jammers. Third, it is necessary to minimize the impact on friendly, unmodified receivers and maximize interoperability. Advanced waveforms, demonstration of an advanced beam shaping transmit antenna, precise management of the radiated power, and the associated command and control structure will therefore be developed. The GPX program will culminate with integrated demonstrations of APL capability in military exercises.

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(U) The Microelectromechanical Sensor Inertial Navigation System (MEMS INS) program will improve the silicon based, inertial sensors (gyros and accelerometers) developed in the MEMS technology program and integrate them with navigation software into a low power, small, light weight, low cost, tactical grade (1.0 degree per hour to 10 degrees per hour drift rate) INS. In addition to handheld applications, the MEMS INS will be generic for insertion/embedding into other military systems. MEMS INS Phase 1 performed the following: (1) design and development of higher performance MEMS inertial gyroscope and accelerometer sensors, (2) selection and refinement of foundries/foundry processes, (3) design of the mechanical subsystem, and (4) selection/refinement of the navigation software. Phase 2 will develop the MEMS inertial sensors brassboard, integrate them into a MEMS INS and demonstrate the brassboard in the field. Three prime contractors are proceeding in Phase 2. Technologies also are being developed for mesoscale gyros. These will be designed, developed and tested at the gyro level. Subsequently, a triad of meso gyros will be integrated and demonstrated as a meso inertial measurement unit. The MEMS and Meso technologies will be evaluated for suitability to space applications.

(U) The Advanced Tactical Targeting Technology (AT3) program will demonstrate a passive tactical targeting system against short-dwell emitters for the lethal suppression of enemy air defenses (SEAD). The targeting system must negate emitter shutdown tactics now employed to defeat Anti-Radiation Missles (ARM) guidance and enable simplified ordnance inventories. Generation and distribution of near real-time (e.g., seconds) comprehensive, and highly precise location of threat radars to all theater combatant aircraft is required without deploying any extra, SEAD dedicated, emitter-collecting platforms. AT3 will accomplish this by widely deploying emitter collection packages hosted on existing airborne platforms, including combatant aircraft. AT3 will integrate in real-time the distributed multi-platform emitter collections using existing or planned tactical data links with advanced network management and signal processing. Additionally, to achieve the necessary wide deployment, AT3 will transition to the Services either as self-contained affordable collection packages or via inexpensive digital upgrades to existing radar warning receivers. Enabling technologies now in development at DARPA and elsewhere will be used, including: highly precise tactical clocks; tightly coupled integrated GPS/INS packages; novel communications waveforms; advanced highly dynamic data fusion network management capabilities; and algorithms to ensure robust, flexible performance of geolocation algorithms for locating multiple emitter types in noisy, high pulse density environments.

(U) The Multifunction Electro-Optics for Defense of U.S. Aircraft (MEDUSA) program will develop the technologies and systems to give the U.S. air dominance at low altitude and at night. This program will develop the technologies to leap-frog reactive end game countermeasures and enable increased threat warning times, denial of launch, and put EO-IR air defense threats at risk. MEDUSA is a three-part technology program: (1) conduct phenomenological measurements and develop countermeasures and target classification/identification techniques; (2) develop critical

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component technologies such as high power IR laser sources, advanced IR detectors, and fibers for high power IR transmission; and (3) competitively develop and demonstrate an end-to-end MEDUSA system.

(U) **Program Accomplishments and Plans:**

(U) **FY 2001 Accomplishments:**

- Global Positioning Experiments (GPX). ($3.975 Million)
  - Completed development and evaluation of elements of the pseudolite network.
  - Completed lab and initial field demonstrations of a digital adaptive beamformer with multi-element antenna.

- Microelectromechanical Sensor Inertial Navigation System (MEMS INS). ($4.387 Million)
  - Evaluated brassboard sensors and electronics.

- Advanced Tactical Targeting Technology. ($11.850 Million)
  - Completed fabrication and began ground tests.
  - Initiated advanced algorithm development.
  - Completed study of EO/IR surface-to-air-missile fire control targeting.

(U) **FY 2002 Plans:**

- Global Positioning Experiments (GPX). ($8.000 Million)
  - Complete demonstration of digital adaptive beamformer integrated with pseudolite in a GPS jamming environment.
  - Initiate fabrication of multiple airborne pseudolites.

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- Microelectromechanical Sensor Inertial Navigation System (MEMS INS). ($5.000 Million)
  - Deliver MEMS inertial measurement unit to the Government.
  - Complete field demonstration of MEMS INS navigation capabilities.
  - Demonstrate meso gyro with 1 degree per hour performance.
  - Investigate novel INS designs for very large structures that exploit large baseline separation.
  - Investigate MEMS and Meso suitability to space applications.

- Advanced Tactical Targeting Technology. ($13.401 Million)
  - Complete ground tests.
  - Initiate strenuous flight tests and real-time multi-ship demonstrations.

- MEDUSA. (11.000 Million)
  - Develop and evaluate MEDUSA countermeasure and classification techniques and conduct phenomenological measurements.
  - Initiate critical component and system technology development.

(U) **FY 2003 Plans:**

- Global Positioning Experiments (GPX). ($9.500 Million)
  - Complete airborne pseudolite fabrication and integration.
  - Conduct airborne testing campaign; demonstrate successful navigation and interoperability in GPS jamming environment using multiple airborne pseudolites.

- Microelectromechanical Sensor Inertial Navigation System (MEMS INS). ($6.000 Million)
  - Develop an inertial measurement unit based on meso gyro technology.
  - Conduct preliminary meso gyro navigation tests.
  - Begin system design for user (Service) test.

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- Advanced Tactical Targeting Technology. ($10.500 Million)
  - Complete experimental data analysis.
  - Complete field demonstrations.

- MEDUSA. ($18.000 Million)
  - Complete measurements database and development of countermeasures and classification techniques.
  - Fabricate and evaluate critical component technologies.
  - Develop MEDUSA system designs.

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

- Not Applicable.

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

Plan	Milestones
Feb 02	Complete laboratory demonstration of MEMS INS operations.
Apr 02	Complete AT3 ground tests.
Jul 02	Demonstrate meso gyro performance.
Jun 02	Complete field test/demonstration of MEMS IMU.
Jul 02	Demonstrate GPX airborne pseudolite operation with digital beamformer in GPS jamming.
Dec 02	Complete AT3 real-time flight tests.
Jul 03	Complete design of meso IMU.
Jun 03	Demonstrate an integrated GPX pseudolite system with weapons in jamming environments.
Aug 03	Complete AT3 data analysis and field demonstrations.
Sep 03	Complete MEDUSA measurements database and system designs.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Aerospace Surveillance Technology SGT-02	23.142	23.732	28.000	24.849	24.789	24.792	19.753	Continuing	Continuing

(U) Mission Description:

(U) This project funds sensor efforts that will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability and battle damage assessment. Timely surveillance of enemy territory under all weather conditions is critical to providing our forces with the tactical information needed to succeed in future wars. This operational surveillance capability must continue to perform during enemy efforts to deny and deceive the sensor systems, and operate, at times, in a covert manner. This project will exploit recent advances in multispectral target phenomenology, signal processing, low-power high-performance computing, and low-cost microelectronics to develop advanced surveillance and targeting systems. Surveillance is not an end to itself, but rather an enabler for force protection and precision strike. Therefore, a key component of this program is the development of a comprehensive sensor-to-shooter architecture.

(U) The Digital Radio Frequency Tags program will develop a flexible, potentially low cost technology to allow radars (Moving Target Indicator (MTI) and Synthetic Aperture Radar (SAR)) to receive data from ground devices. This program will develop a small, lightweight and affordable RF Tag for data exfiltration from unattended ground sensors and communication with vehicles and personnel throughout the battlespace. This is particularly useful for the identification and location of coalition units. Additionally, the Digital RF Tag capability can be exploited for other missions, with the net effect of substantially enhancing situational awareness and combat identification advantages for U.S. forces in conventional and unconventional ground operations.

(U) Underground Facilities (UGFs) are being increasingly employed to hide a variety of strategic functions, including command and control and activities associated with weapons of mass destruction. The Counter-Underground Facilities (CUGF) program will develop technologies to characterize UGFs: identification of facility function, UGF pace of activity, pre-attack status of the facility, trans-attack activities and post-attack status. Techniques will be developed to determine locations of critical systems (power, water, airflow vents), orientation and depth of structure, and pre-strike and post-strike changes in the substructure resulting from attack. Additionally, techniques will be developed for effluent detection and monitoring. Candidate technologies include, but are not limited to, low frequency electromagnetics, multi/hyperspectral imaging, seismic imaging, chemical sampling, and coherent passive seismic, acoustic and electromagnetic monitoring. A companion effort, the Tactical Missile – Penetrator (TACM-P) program, will demonstrate integration of the Army Tactical Missile System (ATACMS) booster with a Navy reentry vehicle to provide a

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high-availability, all-weather, survivable and short response time means to destroy hard and deeply-buried targets. U.S. Pacific Command is the operational sponsor.

(U) The Space Surveillance Telescope program will develop and demonstrate an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability. The program will leverage recent advances in curved focal plane array technology and large, light-weight optics to build a telescope with a large aperture that provides detection sensitivity with a low-aberration wide field-of-view to provide rapid wide-area search coverage. Advances in lightweight optics will reduce the size and weight of the telescope, providing fast slewing and further increasing search rates. This capability will enable ground-based detection of un-cued objects in space for purposes such as asteroid detection and other defense missions. In FY 2003, this program will be funded from PE 0603285E, Project ASP-02, Space Programs and Technologies.

(U) The Near-Nadir MMW Exploitation System (NEMESYS) will detect and identify targets under trees using an ultra-high resolution, 3D Ka-band SAR flown on a small UAV. By imaging at steep grazing angles, foliage penetration losses and phase perturbations at millimeter wave frequencies are minimized. Three-dimensional images are formed by using a combination of wide bandwidth waveforms to obtain height resolution, conventional SAR to provide along-track resolution, and a virtual SAR created by activating sequential elements of a linear array to provide cross-track resolution. Multiple images of the target are formed to allow 3D rendering. Target scatterer locations are correlated with 3D CAD models to provide a simple, robust and inexpensive form of ATR.

(U) The Large Millimeter Wave Telescope (LMT) program is the U.S.-complement to a coordinated U.S.-Mexico project. The DARPA program is providing technology assessments for design, systems integration and technology-leading metrology for a 50-meter aperture, fully steerable millimeter wave radio telescope. The fully developed telescope features a sophisticated laser metrology system to maintain precise alignment of the optics, and real-time closed loop adaptive control to maintain a near-perfect parabolic surface at all pointing angles and under most environmental conditions.

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

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

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- Digital Radio Frequency (RF) Tags. ($7.998 Million)
  - Completed critical design review (CDR) for digital RF tag.
  - Completed definition of message embedding and extraction algorithms.
  - Conducted component risk reduction tests on brassboard system.

- Counter-Underground Facilities. ($11.144 Million)
  - Completed baseline models of signatures and backgrounds for passive acoustic, seismic, electromagnetic (PASEM), and effluents observables.
  - Initiated model validation experiments.
  - Completed modeling tools for evaluation of effluent based vent hunting.
  - Completed preliminary validation experiments for vent effluent denial & deception simulation tools.
  - Initiated interface requirements definition and initiated hardware/software design for the Tactical Missile – Penetrator (TACM-P).

- Large Millimeter Telescope. ($4.000 Million)
  - Completed detector/pointing system baseline controls.
  - Completed telescope critical design review.
  - Completed foundation and deep support piles.
  - Completed fabrication of Azimuth component track and pintle bearing.

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

- Digital Radio Frequency (RF) Tags. ($5.600 Million)
  - Perform software design, coding and test.
  - Complete tag breadboard unit.
  - Conduct laboratory device testing and characterization.

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- Counter-Underground Facilities. ($12.532 Million)
  - Complete model validation for seismic, acoustic, electromagnetic and effluent signatures and backgrounds.
  - Complete hardware/software design and initiate missile re-entry body system tests of the Tactical Missile – Penetrator (TACM-P).
  - Complete interface definition and continue hardware/software design for the Tactical Missile – Penetrator (TACM-P).
  - Initiate design for passive acoustic, seismic, electromagnetic (PASEM) functional prototype demonstration (non-form factored).
  - Initiate concept development for low-mass, seismic coupling of vibration sensors, site-adaptive non-line of sight communications, and improved deployable EM sensors.
  - Complete validation of effluents modeling tools.
  - Initiate concept evaluation for specific techniques for effluent based vent hunting.

- Space Surveillance Telescope. ($4.100 Million)
  - Complete telescope design.
  - Complete focal plane design.
  - Fabricate and test first curved focal plane tile.

- Large Millimeter Telescope. ($1.500 Million)
  - Initiate fabrication of metrology panel and surface.
  - Initiate antenna holography system.
  - Initiate precision pointing.

(U) <u>FY 2003 Plans:</u>

- Digital Radio Frequency (RF) Tags. ($5.500 Million)
  - Complete tag prototype units.
  - Conduct airborne field tests and user demonstration.
  - Develop low frequency RF tags for use under foliage.

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- Counter-Underground Facilities. ($12.500 Million)
  - Complete passive acoustic, seismic, electromagnetic (PASEM) functional prototype system demonstration design and hardware integration.
  - Evaluate performance of low-mass, seismic coupling concepts for vibration sensors (rock, loose rock, unconsolidated soils).
  - Conduct pairwise nodal evaluation of site-adaptive non-line of sight communication concepts; make Go/NoGo Decision for multimode development.
  - Evaluate improved deployable EM sensors: noise performance for small devices, self orientation and calibration algorithms; make Go/NoGo Decision for deployable sensor completion.
  - Complete concept definition for effluent based vent hunting and initiate prototype design.

- Near-Nadir MMW Exploitation System (NEMESYS). ($10.000 Million)
  - Conduct antenna proof of principle study.
  - Measure 1-D synthetic aperture signatures of canonical targets through canopy.
  - Begin development of target and clutter models.
  - Begin development of signal processing, visualization tools and automatic target recognition algorithms.

(U) **Other Program Funding Summary Cost:** *(In Millions)*

	FY 2001	**FY 2002**	**FY 2003**
Tactical Missile – Penetrator (TACM-P):			
Source OSD/ASCE PE 0603750D8Z	4.300	6.600	7.500

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(U) Schedule Profile:

Plan	Milestones
Digital Radio Frequency (RF) Tags:	
Nov 02	Prototype RF tag component hardware fabrication and testing complete.
May 03	Prototype digital tag testing complete.
Sep 03	Field test of prototype tag.
Counter-Underground Facilities:	
Sep 02	Complete passive acoustic, seismic, electromagnetic (PASEM) functional prototype/demonstration system design.
Sep 02	Complete hardware/software design for re-entry body. Conduct CDR and initiate flight hardware fabrication.
Sep 03	Complete PASEM functional prototype system integration.
Near-Nadir MMW Exploitation System (NEMESYS):	
Oct 02	Initiate target and clutter measurement and modeling efforts.
Oct 02	Initiate development of signal processing, visualization tools, and ATR algorithms.
Jun 03	Conduct Preliminary Design Reviews (PDR).

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Air Defense Initiative SGT-03	21.236	24.155	31.000	37.770	30.738	28.792	24.938	Continuing	Continuing

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

(U) This project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats. These technology developments are embodied in the Low-Cost Cruise Missile Defense (LCCMD), Global Eye, Affordable Large-Scale Array (ALSA), Innovative Space-Based Radar Antenna Technology (ISAT) Study and Polarized Infrared Imaging Seeker (PIRIS) programs.

(U) The LCCMD program will design, develop, demonstrate and transition an affordable seeker for use on a missile interceptor system to defeat unsophisticated air vehicles. Unsophisticated air vehicles are affordable, can be procured in large numbers to overwhelm U.S. defenses and provide a credible long-term threat to both civilian population centers and military targets. To reduce the cost of defending against such threats, it is crucial to reduce the cost of the guidance and control sections of defensive weapons. The LCCMD program will enable this through analyses, laboratory testing and field-testing of an all-weather seeker costing less than fifty thousand dollars in production. The program has pursued six novel concepts and is presently focused on the maturation and demonstration of radar seeker solutions employing MEMS phase shifters and novel waveforms. In addition, the program is examining low-cost surveillance strategies to provide the warning/cue for such interceptors.

(U) The Global Eye program is developing lightweight low-cost electronically scanned array (ESA) technology that is capable of supporting multiple simultaneous radar modes and frequencies through the use of mono-static or pseudo-mono-static apertures operating in a simultaneous transmit and receive (STAR) mode. Platforms outfitted with this capability could provide lower cost continuous air and ground surveillance of low intensity areas such as no-fly zones and peacekeeping areas. Such capability could supplement traditional AWACS and JSTARS and potentially reduce the requirement to forward base large numbers of such aircraft for these purposes. The key technologies being developed include a proof-of-concept ESA risk reduction array capable of supporting a 100% transmit duty factor using currently available transmit/receive (T/R) modules, beam polarization diversity, and advanced mode control/interleaving algorithms.

(U) The Affordable Large-Scale Array (ALSA) (previously the MEM-tenna program) is developing ultra-low cost, lightweight, and low-power density X-Band antenna technologies and components for use in large-scale phased array antennas. MEMS and other alternative low-power-module technologies can be used to produce phased array antenna components that consume a small fraction of the power currently needed by conventional phased arrays, while being considerably lighter weight. It may also be possible to replace hard-wired beam steering control and RF

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manifolds by optical and RF space-fed configurations which will result in significant savings in cost and weight. Using these technologies, very large-scale electronically scanned arrays (ESAs) can be developed for multiple airborne and surface-based surveillance missions, including homeland defense against air threats.

(U) Ultra-low cost, lightweight technologies offer the potential for developing and deploying extremely large antennas in space. Antennas of 100 – 300 sq meters, if feasible and affordable, will enable the revolutionary performance required to conduct true tactical sensing from space. In FY 2002, a one-year, multi-contractor project (ISAT – Innovative Space-Based Radar Antenna Technology) will be conducted to assess and produce feasible and affordable candidate extremely-large-antenna designs capable of performing tactical sensing from space. Follow-on activities for ISAT activities are funded in Program Element PE0603285E, Project ASP-02.

(U) The polarized infrared imaging seeker (PIRIS) program will develop and demonstrate a prototype seeker with an extremely sensitive degree-of-polarization measurement capability to allow for separation of real targets from emerging infrared countermeasures (IRCM) technologies. Current imaging systems rely on spatial, spectral and temporal resolution to separate enemy countermeasures from the target skin return. New ECM technologies, such as activated metal decoys (AMDs), pose significant challenges to systems relying on spatial, spectral and temporal resolution. AMDs provide a spatially distributed source at appropriate temperatures to thwart these conventional approaches. The PIRIS program will develop and demonstrate the technologies required to buy back performance against AMDs using polarization diversity. The PIRIS program will conduct a series of experiments to verify the degree-of-polarization separation of multiple types of countermeasures and targets and will culminate in a captive carry flight test of an advanced polarized seeker capable of defeating the entire range of emerging IRCM threats.

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

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

- LCCMD. ($11.768 Million)
  - Completed laboratory characterization testing of eye-safe LADAR seeker.
  - Designed, fabricated and tested improved RF MEMS capacitive and contact switches for use in MEMS antenna array.
  - Completed noise radar seeker China Lake field-testing.

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- Global Eye. ($3.275 Million)
  - Initiated and completed proof-of-concept studies on the design and fabrication of MEMS-based filters that could be used to facilitate the use of simultaneous transmit and receive (STAR) waveforms.
  - Began risk reduction phased array fabrication and tests.
  - Developed initial concepts and system architectures for advanced radar mode control using a pseudo-mono-static aperture for STAR operation.

- ALSA. ($5.193 Million)
  - Completed fabrication and evaluation of 100 prototype MEMS 2-bit phase shifters from three contractors.
  - Completed follow-on MEMS phase shifter design studies.
  - Conducted trade studies for array calibration techniques with both specific and general applicability.
  - Initiated MEMS lifetime and reliability improvement effort.
  - Initiated efforts to investigate and analyze alternative phased array antenna technologies, including SiGe, InP, and Si on insulator, and low-power GaAs, as potential alternatives for low-cost/low-power density phased array antenna operations.

- Advanced Sensing Alternatives. ($1.000 Million)
  - Explored advanced sensing modalities to solve stressing combat ID and countermeasure challenges, including, but not limited to, polarization diversity and unconventional operating frequencies.

(U) **FY 2002 Plans:**

- LCCMD. ($12.000 Million)
  - Complete noise radar seeker data analysis final report.
  - Conduct MEMS ESA seeker systems requirements and preliminary design reviews.
  - Fabricate and test packaged RF MEMS for use in MEMS antenna array.
  - Initiate MEMS modeling effort and MEMS design improvement/packaging studies for enhanced reliability RF MEMS switches.

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- Conduct studies on low-cost surveillance approaches to supply required threat warning. Determine feasibility of exploiting existing infrastructure, such as cell towers.

- Global Eye. ($1.705 Million)
  - Demonstrate pseudo-mono-static ESA operation using a 1 sq ft risk reduction array.
  - Use the prototype ESA risk reduction array to evaluate its ability to support multiple-mode, multiple-frequency, and radar operation during ground testing with a Moving Target Simulator (MTS) and a mechanically scanned receive aperture.

- ALSA. ($3.450 Million)
  - Conduct studies and experiments to develop alternative array feed technologies that are applicable to very large arrays.
  - Continue investigation and evaluation of alternate solutions, e.g., SiGe, InP, Si on insulator, and low-power GaAs, as potential low cost/low power density phased array antenna technologies.
  - Conduct power-aperture trade studies to determine the appropriateness of these technologies for applications including ground-based or airborne low-power-density, large-scale antennas for homeland defense.
  - Develop and fabricate a minimum of 10 transmit/receive (T/R) cells for independent test and evaluation.

- ISAT. ($6.000 Million)
  - Develop detailed conceptual designs of multiple antenna systems.
  - Develop performance and cost models for each candidate design and associated technologies.
  - Identify critical technologies and risk reduction requirements.
  - Model and simulate rigidized inflatable technologies.

- PIRIS. ($1.000 Million)
  - Conduct field experiments to verify degree-of-polarization separation of targets and infrared countermeasures.
  - Initiate polarized seeker component technology studies and development.

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(U) **FY 2003 Plans:**

- LCCMD. ($17.000 Million)
  - Conduct MEMS ESA seeker critical design review.
  - Fabricate and test MEMS ESA seeker antenna.
  - Fabricate MEMS ESA seeker back-end.
  - Initiate procurement of long-lead items for captive flight test (in collaboration with service transition partner).
  - Conduct iterative design, fabrication and testing of advanced RF MEMS designs for EMD-quality RF MEMS switches.
  - Initiate systems design for low-cost surveillance approaches.
  - Initiate field measurements to support performance characterization of surveillance systems.
  - Conduct small-scale feasibility demonstration.

- ALSA. ($10.000 Million)
  - Develop system-level conceptual designs for low-power-density surveillance applications.
  - Estimate system-level performance achievablefor low power density surveillance applications.
  - Initiate risk reduction activities for these designs, including deployment/unfolding technologies appropriate to large-scale structures.

- PIRIS. ($4.000 Million)
  - Conduct critical hardware risk reduction experiments.
  - Conduct preliminary design of prototype-polarized seeker.

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

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

<u>Plan</u>	<u>Milestones</u>
LCCMD:	
Aug 02	Complete systems requirements and preliminary designs.
Feb 03	Conduct MEMS ESA seeker critical design review.
Apr 03	Complete system-level conceptual designs for low-cost surveillance systems.
Sep 03	Complete EMD quality RF MEMS switch design, fabrication and test.
Sep 03	Complete estimation of system-level performance for surveillance approaches.
Sep 03	Complete initial feasibility demonstration.
Oct 03	Start MEMS ESA seeker antenna test.
Global Eye:	
Apr 02	Complete fabrication of a basic ESA risk reduction array and begin testing of the array.
Aug 02	Complete pseudo-mono-static multiple frequency multiple-mode demonstrations using the risk reduction array.
ALSA	
Mar 02	Begin fabrication of a minimum of 10 T/R cells.
Jun 02	Conduct testing of 10 T/R cells.
Apr 03	Complete system-level conceptual designs.
Sep 03	Complete estimation of system-level performance.
Sep 03	Demonstrate deployment of large structure.
ISAT:	
May 02	Preliminary conceptual designs.
Jun 02	Preliminary large aperture control and calibration analysis.
Sep 02	High-fidelity steady state and dynamic models of rigidized inflatable designs.
Sep 02	Complete conceptual designs.

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Oct 02	Conceptual design presentations and supporting analysis.

PIRIS:

Sep 02	Complete degree-of-polarization field experiments.
Jun 03	Complete risk reduction hardware experiments.
Sep 03	Complete preliminary design for prototype.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Sensors and Exploitation Systems SGT-04	73.918	106.807	121.000	105.517	90.367	90.200	90.865	Continuing	Continuing

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

(U) The Sensors and Exploitation Systems project funds the development and demonstration of advanced sensors and systems to exploit sensor products. These efforts, in conjunction with those described in Projects SGT-01, SGT-02 and SGT-03, seek to develop the systems needed to provide the warrior with situational awareness and precision target identification and attack capability, with particular emphasis on the most stressing threats. The strategic goals of this project are to: develop key sensor technologies required to support battlefield dominance, including sensors that can counter Camouflage, Concealment and Deception (CC&D); provide near-real-time, semi-automatic exploitation of wide-area moderate (and high) resolution imagery; provide real-time, accurate Battle Damage Assessment (BDA); and provide robust, precise and reliable identification, precision fire control tracking and engagement of high value units, and critical moving targets. These goals are being addressed by the following programs: Counter CC&D; Affordable Moving Surface Target Engagement (AMSTE); Organic Ground Moving Target Identification (GMTI) Radar (OGR); Eyeball Program; Real-Time Battle Damage Assessment (R/T BDA); Tactical Targeting Network Technologies (TTNT); Dynamic Tactical Targeting (DTT); and the Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER), a multispectral electro-optical (EO)/infrared (IR)/radar identification concept. Three new initiatives: Dynamic Tactical Sensing, Exploitation of Precision Data, and Tactical Sensor Network Technologies will be funded in FY 2003.

(U) The goal of the Counter Camouflage, Concealment and Deception (CC&D) program is to significantly enhance the military's capability to detect obscured targets hidden under foliage and camouflage. Specific goals include validation of Foliage Penetration (FOPEN) target detection and false alarm rejection capability. The FOPEN SAR is being developed for demonstration on a manned platform providing inputs via narrowband tactical data links for ground image exploitation. A Ground Control and Display Subsystem is being developed to provide real-time, remote operation of the FOPEN SAR, Automatic Target Detection and Cueing and a Common Imagery Ground/Surface System-compliant exploitation interface. The image exploitation processing of SAIP will be extended via the Multisensor Exploitation Testbed for FOPEN. Efforts are also being undertaken to evaluate the capability for FOPEN Ground Moving Target Identification and Electronic Support Measures to increase the effectiveness of future Counter CC&D systems.

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(U) The goal of the Affordable Moving Surface Target Engagement (AMSTE) program is to develop and demonstrate the technologies required to perform affordable, all-weather, precision negation of moving surface targets (both land- and sea-based), from stand-off ranges using netted tactical and theater ground moving target indication (GMTI) sensors and weapons. The precise cueing from the netted GMTI sensors will allow for lower-cost weapons by reducing the complexity of precision munitions. Weapons system architectures will be developed and integrated to support a series of precision fire control bomb-drop field experiments and demonstrations. In-flight midcourse and terminal guidance to weapons will also be implemented to demonstrate weapon system accuracy that is an order of magnitude better than current systems against moving targets. A number of critical technologies must be developed including unaided precision grid locking techniques, low-cost weapon data links, low-cost weapon seekers and advanced multi-platform tracking algorithms for both precision and long-duration, high-confidence track purity using moving target feature phenomenology for track maintenance. Additionally, battle management, command, control and communications (BM/C3) experiments will be pursued jointly with Service partners to enable rapid inclusion of AMSTE-enabled engagement capabilities into future operational architectures.

(U) The objective of the Organic Ground Moving Target Identification (GMTI) Radar (OGR) program is to develop the technologies required to enable a low-cost capability for the ground-based detection and tracking of moving vehicles and personnel through foliage. The goal is to detect vehicles at ranges of 5-10 km and personnel at ranges of 1-3 km with low false alarm rates. One concept is based on the use of separate transmitters and receivers that are designed for low cost and portability. The transmitter can be either an "organic" transmit asset that is attached to an Army or Marine unit, or a non-cooperative emitter of opportunity such as a HDTV station or an airborne transmitter. False alarm reduction and target tracking will be achieved through the creation of multiple narrow azimuth receive beams using high-speed digital beam forming computers. To ensure adequate foliage penetration, the system will be designed to operate in the VHF-UHF frequency regime. A second concept is to deploy small L-Band monostatic radars at high altitude (e.g. 500-1500 m) and gain foliage penetration through steep look-down angles.

(U) The goal of the Eyeball program is to develop and demonstrate novel concepts for precision target identification (ID) of moving and stationary tactical targets from standoff platforms by electro-optical sensors working in conjunction with air- and space-based radar GMTI and SAR sensors. This program is motivated by the expectation that while future radar assets will have the capability to perform target detection, location and tracking, and even some forms of target classification, target ID performance will be insufficient to allow targeting and allocation of attack assets due to radar and signature limitations. The Eyeball sensor will exploit the benefits of combining spatial, spectral and polarimetric signatures from sparse or filled apertures to enable real-time precision ID of critical tactical targets. In the concept of operations, a GMTI-SAR platform hands-off moving and stationary target location information to the Eyeball sensor. Eyeball identifies the target at standoff ranges and returns the target ID to the radar for track file association. Through episodic revisits by Eyeball, the GMTI-SAR platform maintains continuous track of the identified

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tactical target. The critical aspect of this program is to understand what is required in terms of combined spatial, spectral, and polarimetric signatures and resolution trades across the sensing domains to realize the required target ID performance. To achieve this critical understanding, the Eyeball program will conduct phenomenology, modeling, architecture/system trades, and ground-based experiments to validate and demonstrate the technology.

(U) The goal of the Real-Time Battle Damage Assessment (R/T BDA) program is to develop and evaluate technology to permit all-weather, in-theater assessment of the effects of precision weapons on mobile threats. R/T BDA will exploit synthetic aperture radar sensors, including organic and theater sensors, to assess effectiveness of munitions delivery and provide feedback to attack systems during the mission, with a goal of providing weapon effectiveness feedback to the operator within 10 minutes of engagement. R/T BDA will also explore very low-cost, “pop-off” sensors deployed from incoming weapons at pre-determined times before weapon impact. R/T BDA will focus on identifying and assessing weapons effects from precision guided munitions, submunitions, sensor-fuzed weapons, and similar weapons that typically provide less energetic effects on the target and are therefore more difficult to assess by traditional BDA techniques.

(U) The Tactical Targeting Network Technologies (TTNT) program will develop, evaluate and demonstrate rapidly reconfigurable, affordable, robust, interoperable and evolvable communications technologies specifically to support networked targeting applications. There is an increasing trend across the Armed Services towards the use of tactical computer-to-computer communications networks (ex. JTIDS) for a variety of missions. Emerging networked targeting applications, designed to keep fleeting targets at risk, impose unprecedented network reconfigurability demands. Specifically, the program will develop and demonstrate a prototype distributed tactical network that will be reconfigurable in fractions of a second, have wideband capacity on demand, have near zero latency, facilitate transparent operation within existing links, and be inexpensive enough to be ubiquitous. Technologies to be developed include wideband waveform underlays, and rapid network planning tools and advanced network simulations.

(U) The Dynamic Tactical Targeting (DTT) program will develop new sensor control and fusion technologies that will leverage technology developed in the Dynamic Database (DDB) and Advanced Intelligence, Surveillance and Reconnaissance (ISR) Management (AIM) programs to enable a tactically responsive targeting process to be managed by Warfighters. The DTT program will design, build and demonstrate a system that will: a) leverage existing National/Theater intelligence, surveillance and reconnaissance (ISR) processes for timely extraction of critical data; b) register in-situ sensor data with ISR data to conduct geo-spatial and temporal registration of all sensor data by leveraging, for example, devices from the Digital Radio Frequency Tags (DraFT) program to perform as multi-spectral transponders; c) fuse in-situ sensor data with ISR data from all sources to enable multi-scale estimation of target location, identity and activity; d) dynamically task in-situ sensors to fill ISR coverage gaps and

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provide relevant sensor observation in areas of tactical interest; and e) process and manage the large volume of data produced by all these sensors in time to provide needed information to shooters. One of the important products at the end of the DTT program will be a testbed capable of demonstrating closed loop (data fusion and sensor management) operation to support real time targeting of mobile TCTs in a field environment.

(U) The Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER) program will radically alter the fundamental "front-end" signal processing architectures within the radar discipline through the real-time integration of dynamic environmental knowledge to dramatically improve clutter and interference rejection and significantly enhance sensor products. All conventional and advanced RF sensors that employ any form of adaptive signal processing estimate the background interference using the same data that is used for target detection. Additionally, it is assumed that the background interference over the region used to perform the estimation is stationary and homogeneous. This assumption is not valid – numerous sensors have demonstrated so in real environments around the world. This problem manifests itself in increased false alarms, decreased target detections, and substantially degraded minimal detectable velocities in GMTI systems. KASSPER will leverage the advent of detailed databases and high fidelity models to incorporate inhomogeneities and non-stationarity at the very front end of adaptive signal processing systems. Key technologies to be developed include advanced algorithms and high-performance computing architectures capable of performing very memory intensive adaptive signal processing. Extensive data collections will be carried out and the program will culminate in a real-time demonstration of its processing gains on military aircraft in both monostatic and bistatic modes.

(U) The new Dynamic Tactical Sensing initiative will develop sensors, signal processing, and sensor exploitation tools to close gaps in coverage achievable with current sensors. These will range from small, close-in sensors that confirm specific target characteristics, to large, standoff sensors that detect target indicators over wide areas.

(U) The objective of the new Exploitation of Precision Data initiative will be to combine data from a variety of sensors, of different types (especially radar, video, and lidar), into an extremely high confidence assessment of target type and operational status. It will develop target signatures both from models and data collected from real-time operations, match those against new data, and confirm that a particular vehicle is, or is not, a valid target.

(U) The objective of the new Tactical Sensor Network Technologies (TSNT) initiative will be to build detection, tracking, identification, and pattern analysis algorithms that operate at all nodes within a networked system. The actual processing to be performed at each network node will depend on the sensors reporting to that node, the commanders subscribing to that node, and load-balancing performed at the algorithm level. The

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product will be truly distributed situation awareness, resilient to the failure of any individual node, but sufficiently consistent to serve as the basis for collaborative tactical planning.

(U) **Program Accomplishments and Plans:**

(U) **FY 2001 Accomplishments:**

- Counter Camouflage, Concealment and Deception (CC&D). ($18.658 Million)
  - Completed FOPEN SAR preliminary flight test.
  - Completed first FOPEN SAR development flight test to gather data on targets and background algorithm training.
  - Continued FOPEN GMTI/ESM data analysis and signal processor development to mitigate false alarms and clutter contamination.
  - Completed SAR and spectral data fusion analysis.
  - Conducted wide-band FOPEN GMTI experiment.

- Affordable Moving Surface Target Engagement (AMSTE). ($35.376 Million)
  - Designed, developed and fabricated the initial field experiment system, including airborne sensors modified to support real-time fire control and a weapon data link.
  - Conducted field experiments to evaluate the capability to perform precision fire control targeting against moving targets, culminating in an inert weapon drop.
  - Evaluated data recorded during field experiments. Laboratory analyses included investigation of various levels of sensor performance, use of a low-cost terminal guidance seeker and extrapolation to operational systems.
  - Conducted Link –16 network planning experiments with Air Force, Navy, Army and USMC at Nellis AFB. The software generated for these experiments has been employed since the initiation of Operation Enduring Freedom to design Link 16 networks
  - Developed advanced target track maintenance techniques for integration into the precision fire control tracker and test in the laboratory on recorded data to support subsequent AMSTE field experiments.
  - Developed advanced GMTI processing approaches to mitigate track contamination.

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- Organic Ground Moving Target Identification Radar (OGR). ($7.610 Million)
  - Completed studies for advanced transmit and receive antenna concepts.
  - Completed detailed data collections at multiple sites using both airborne and ground based transmitters to characterize propagation effects, radar phenomenology and system performance.
  - Demonstrated target detection using VHF HDTV station as transmitter.

- Eyeball. ($1.817 Million)
  - Conducted concept definition including phenomenology assessment, spatial-spectral-polarimetric trades, modeling and simulation, and experiment requirements definition.
  - Initiated the sensor testbed design and perform risk mitigation activities.
  - Linked polarimetric model enhancements into the Spectropolarimetric Sensor Evaluator, developed new model elements and validated against measured data sets.

- Real-Time Battle Damage Assessment (R/T BDA). ($10.457 Million)
  - Conducted RF data collection efforts, including both in-flight and turntable collections.
  - Identified preliminary RF techniques to exploit change detection to identify weapons-effects signatures in synchronized pre- and post-strike SAR imagery.
  - Initiated algorithm development to exploit thru-strike radar phase history data, and identified a promising approach involving cross-range energy “smearing” at the time of the strike.
  - Initiated precision munition “pop-off” BDA sensor conceptual designs for a range of weapons.

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

- Counter Camouflage, Concealment and Deception (CC&D). ($15.120 Million)
  - Complete FOPEN SAR development flight tests.
  - Conduct FOPEN SAR validation flight tests to demonstrate that the FOPEN system meets the target detection and false alarm goals.
  - Conduct user demonstrations of the FOPEN SAR in conjunction with Army and Air Force exercises.

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- Continue developing techniques for false alarm and clutter contamination mitigation.
- Collect data to support terrain characterization under foliage.

• Affordable Moving Surface Target Engagement (AMSTE). ($40.962 Million)
  - Completed design, development and fabrication of an enhanced field experiment system to support evaluation of moving target engagement capabilities.
  - Developed and evaluated signature aided tracking approaches, sensor modes, and sensor mode management to support long-term track maintenance.
  - Conducted field experiments to evaluate the capability to provide complete kill-chain integration from standoff detection, through continuous track maintenance, to the precision fire control end game targeting of moving vehicles. Field and laboratory experimentation were focused on complex target densities, target dynamics, and enhanced bias estimation/removal approaches.
  - Demonstrated a full AMSTE weapons delivery capability in live weapons drops with complex target dynamics.
  - Integrated advanced target track maintenance techniques into the system to support field experiments.

• Organic Ground Moving Target Identification Radar (OGR). ($4.186 Million)
  - Integrate advanced receiver and antenna with OGR baseline system.
  - Demonstrate increased tunable bandwidth receive system.
  - Perform HDTV transmitter experiments using both VHF and UHF illuminators.
  - Perform L-Band radar development and testing
  - Conduct operational demonstrations of the OGR system.

• Eyeball. ($5.663 Million)
  - Complete sensor testbed design including selected aperture and spectral-polarimetric sensor configurations.
  - Conduct a critical design review (CDR).
  - Release testbed long lead times and initiate development of fabrication and test plans.
  - Complete polarimetric modeling development and integration into Spectropolarimetric Sensor Evaluator.
  - Initiate development of target detection and identification algorithms.

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- Real-Time Battle Damage Assessment (R/T BDA). ($12.691 Million)
  - Evaluate robust candidate RF algorithmic techniques against data collected from instrumented live fire testing.
  - Develop planning and sensor management tools to support R/T BDA BM/C3.
  - Develop 3-D, geometry-based, coupled target signature/weapons effectiveness assessment models.
  - Conduct preliminary design review of weapon mounted BDA sensor.

- Tactical Targeting Network Technologies (TTNT). ($9.089 Million)
  - Complete studies, simulations and initial feasibility experiments.
  - Conduct risk reduction experiments for critical components.
  - Define infrastructure requirements

- Dynamic Tactical Targeting (DTT). ($9.096 Million)
  - Define and apply a methodology that allows design and implementation of an information collection/processing and assessment system for the DTT application.
  - Develop an information architecture that is adaptable to the individual user needs at multiple levels of command engaged in diverse missions.
  - Develop models for selected in-situ sensors.
  - Build and validate models for a dynamic, context sensitive information process.
  - Develop approaches to effectively and dynamically register all information products from in-situ, ISR and mapping sources.
  - Develop new adaptive fusion techniques (e.g. adaptation logic beyond that associated with selecting among “fusion engines”) for alignment, association, and estimation.

- Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER). ($10.000 Million)
  - Initiate advanced algorithm development using simulated data sets to identify knowledge source requirements.
  - Collect highly instrumented monostatic data sets.
  - Develop KASSPER Constant False Alarm Rate and Radar (CFAR) algorithms exploiting database and expert reasoning techniques.
  - Define high performance embedded computing architecture to enable rapid memory access.

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- Initiate advanced algorithms for real-time demonstration.
- Initiate development for real-time, high-dimensionality KASSPER software.

(U) **FY 2003 Plans:**

- Affordable Moving Surface Target Engagement (AMSTE). ($28.090 Million)
  - Complete design, development and fabrication of the final field experiment system to support demonstration and evaluation of moving target engagement capabilities in an integrated operational environment.
  - Conduct field experiments utilizing realistic threats, environments and threat doctrine to demonstrate and evaluate the capability to provide a complete, integrated end-to-end technical capability for targeting and engaging moving vehicles. Demonstration focus will include integration of operational sensors and live weapons with operational battle management/command and control.

- Eyeball. ($4.683 Million)
  - Complete sensor testbed fabrication, integration and testing.
  - Complete sensor testbed data collection and demonstration plans.
  - Complete development of target detection and identification algorithms.
  - Conduct sensor testbed data collects and perform data analysis defining end-to-end sensor validation and sensor requirements.
  - Validate spectral-polarimetric target detection and identification algorithm performance.
  - Demonstrate real-time target identification concept.

- Real-Time Battle Damage Assessment (R/T BDA). ($11.800 Million)
  - Perform integrated R/T SAR BDA experiments/demonstrations utilizing real time tasking, sensor exploitation and effects assessment in live fire environment.
  - Complete CDR and initiate fabrication of weapon mounted BDA sensor.

- Tactical Targeting Network Technologies (TTNT). ($18.927 Million)
  - Complete simulation basis for Hardware-in-the-Loop (HWIL) testing.

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- Complete system and sub-system risk reduction experiments.
- Complete brassboard design.

• Dynamic Tactical Targeting (DTT). ($12.500 Million)
  - Complete selection of appropriate in-situ sensors to fuse with national and theater intelligence, surveillance and reconnaissance (ISR) sensors. Leverage Dynamic Database (DDB) technology to develop algorithms to fuse data from in-situ and ISR sensors. Conduct preliminary data collection and/or simulation to enable fusion development.
  - Define metrics for characterizing behavior of information models developed.
  - Develop and use models and techniques for registering data products across multiple sensors to a common geo-spatial and temporal reference.
  - Leverage DDB and Advanced Intelligence, Surveillance and Reconnaissance (ISR) Management (AIM) closed loop experimentation to develop a multi-sensor collection strategy to enable targeting of mobile time critical targets (TCTs).
  - Complete preliminary design of a transportable DTT testbed that will interface with Service operational systems to enable experiments in field exercises.

• Dynamic Tactical Sensing. ($10.000 Million)
  - Develop sensors and exploitation tools to fill in gaps in DTT sensor coverage, with an emphasis on unambiguous target identification.
  - Conduct analyses and experiments to assess the value of providing stand-off sensor support to tactical ground forces.
  - Conduct analyses and experiments to demonstrate the value of wide-area sensing to rapid, decisive, long-range strike operations.

• Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER). ($15.000 Million)
  - Conduct off-line KASSPER Constant False Alarm Rate & Radar (CFAR) demonstration.
  - Continue advanced algorithm development and performance estimation using simulated and real data sets.
  - Collect highly instrumented monostatic data sets onboard Advanced Airborne Sensor Platform (AASP).
  - Conduct CDR of real-time demonstration of KASSPER CFAR algorithms within the Joint STARS T-3 sensor architecture.

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- Conduct PDR of real-time KASSPER beamforming for AASP platform.
- Initiate real-time test planning and demonstration for AASP.

- Exploitation of Precision Data. ($10.000 Million)
  - Develop tools to classify, identify, and characterize the operational state of ground targets using data from 3D sensors (e.g., LADAR) and structural models of target geometry
  - Extend model-based vision technologies to classify, identify, and characterize the operational state of ground targets from video data.

- Tactical Sensor Network Technologies (TSNT). ($10.000 Million)
  - Develop algorithms for distributed situation assessment at all nodes of a networked group of sensors.
  - Incorporate tracking, target identification, and target assignment algorithms for fully distributed operation.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Foliage Penetration (FOPEN):	
Apr 02	FOPEN SAR testing in southern pine forest.
Jul 02	FOPEN SAR testing of SAM site, surrogate drug lab and terrain characterization.
Sep 02	FOPEN SAR testing in northern flat-floor forest.
Oct 02	Verify FOPEN SAR automatic target detection and cueing (Blind Test).
Affordable Moving Surface Target Engagement (AMSTE):	
Sep 02	AMSTE live weapons demonstration and track maintenance integrated field experiment.

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Aug 03	AMSTE end-to-end system operational demonstration with BM/C3 integration and full threat dynamics.

Organic Ground Moving Target Identification (OGMTI):

Feb 02	Test OGR using VHF and UHF HDTV station as transmitter.
Jun 02	Test L-Band OGR concept
Aug 02	Demonstrate OGR operational utility.

Eyeball:

Jun 02	Complete Eyeball sensor testbed design and fully integrate spectral-polarimetric model into Spectropolarimetric Sensor Evaluator.
Jun 03	Complete Eyeball target detection and identification algorithm development.
Sep 03	Validate Eyeball sensor experiment data collection and system.

Real-Time Battle Damage Assessment (R/T BDA):

Feb 02	Validate R/T BDA coupled target signature/weapons effects models.
May 02	Complete preliminary design of RT/BDA weapon-deployed sensor.
Sep 02	Complete integrated SAR R/T BDA experiment/demonstration design.
Jan 03	Complete CDR of R/T BDA weapon-deployed sensor.
Jul 03	Conduct SAR R/T BDA integrated demonstration.

Tactical Targeting Network Technologies (TTNT):

Jul 02	Complete TTNT common tasks and complete distribution of results to primes.
Aug 02	Complete in-depth studies, simulations and feasibility experiments.
Sep 02	Down select the prime contractors to enter phase two of TTNT.
May 03	Complete all TTNT simulation studies up to and including HWIL.
Aug 03	Complete HWIL testing of candidate TTNT brassboard designs.
Sep 03	Down select the prime contractor(s) to enter phase three of TTNT.

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Dynamic Tactical Targeting (DTT):

May 02	DTT component design completed and evaluated.
Jul 02	DTT technical approach defined and coordinated.
Apr 03	DTT laboratory experiments – validation/selection of components.
Jun 03	DTT components available to system integrator.

Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER):

Apr 02	Radar data collection.
Aug 02	Real-time algorithm Preliminary Design Review.
Mar 03	Multi-channel radar data collection (AASP).
Jul 03	Algorithm Critical Design Review – real-time demo freeze.
Aug 03	High performance embedded computing architecture Preliminary Design Review.
Aug 03	Off-Line demonstration of order of magnitude reduction in false alarm rate for monostatic application.

Dynamic Tactical Sensing (DTS)

May 03	Complete initial experiment plan
Sep 03	Complete initial experiment

Exploitation of Precision Data

Dec 03	Obtain initial set of target models and simulated observational data
Aug 03	Characterize performance of baseline algorithms

Tactical Sensor Network Technologies

Dec 02	Develop initial sensor architecture and concept of employment
Jun 03	Baseline functional components and data flows for tactical scenarios
Sep 03	Test baseline algorithms in single nodes

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COST *(In Millions)*	FY 2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	25.290	36.497	33.000	47.638	74.367	84.116	92.828	Continuing	Continuing
Advanced Ship-Sensor Systems, MRN-02	25.290	36.497	33.000	47.638	74.367	84.116	92.828	Continuing	Continuing

(U) Mission Description:

(U) The objective of the Marine Technology program is to identify, develop and rapidly mature critical advanced technologies and system concepts for maritime applications that support the following goals: 1) maintenance of U.S. naval force access to the littoral by countering the threat created by the worldwide spread of increasingly sophisticated technology; 2) enhancement of the ability of U.S. naval forces to interrogate and dominate the maritime battlespace, particularly in the littoral arena; 3) advances in the ability of U.S. naval assets to conduct operations as a seamlessly networked and integrated theater level force; and 4) improved power projection capabilities of U.S. naval forces, particularly with respect to their ability to influence the land battle. Proliferating threats such as modern cruise missile technology, commercially available overhead surveillance, advanced undersea mine capabilities, and modern, quiet diesel/electric submarines, pose major challenges for operations in the restricted water, near-shore regimes that are of growing importance to U.S. strategic considerations, necessitating continued development of increasingly affordable far-term solutions for enhancing the operating capability and survivability margins of U.S. naval forces in the littoral. This program element funds the Advanced Ship-Sensor Systems project (MRN-02), comprised of the following programs: Undersea Littoral Warfare (ULW), Buoyant Cable Array Antenna (BCAA) program, the Robust Passive Sonar (RPS), the Vortex Combustor Demonstration program, and the Loki Systems Development Program.

(U) The Undersea Littoral Warfare (ULW) program is completing the Netted Search, Acquisition and Targeting (NetSAT) system, a networked approach for improved attack performance that exploits the use of a sonobouy field during the weapon run to identify, locate and mitigate the impact of countermeasures and target evasion tactics on torpedo operation. A bi-directional fiber optic link enables return of torpedo information to a processor servicing the other sensors on the network in addition to providing a command link for the weapon. The ability to rapidly discern the geographic picture from multiple viewpoints is expected to provide major (ten-fold) torpedo performance improvements in strong countermeasure environments while requiring only modest modification of existing torpedo inventories. The NetSat effort completed in FY 2001. Beginning in FY 2003, the ULW program is developing approaches to undersea warfare that will revolutionize the ability to classify and identify underwater objects

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such as mines. The ULW program will also investigate: 1) technologies and demonstrations for locating and tracking maritime targets of interest; 2) innovative sensor and array technologies; 3) technologies and demonstrations enabling unique weapons or payload concepts for potential deployment on submarines and other undersea vehicles; 4) technologies for buried mine identification and classification in the littoral; and 5) technologies and demonstrations enabling small, autonomous, undersea vehicle conceptual designs.

(U) The Buoyant Cable Array Antenna (BCAA) program is developing an antenna capable of supporting full duplex (transmit and receive) connectivity for voice and data with communications satellites while floating on the ocean's surface. Towed behind a submarine, this capability will enable high quality, high data-rate connectivity with other military assets, even while operating at speed and depth. Supporting technologies to be developed include photonic signal and power links, enhanced antenna loading materials, processing algorithms for blind adaptive array calibration and wash over mitigation, advanced communications protocols and signature minimization techniques.

(U) The Robust Passive Sonar (RPS) program is an outgrowth of the successful experiments performed under the Undersea Littoral Warfare Program. The RPS program will investigate the ability of innovative, adaptive processing approaches, coupled as appropriate to arrays providing external information, to suppress the acoustic interference generated by surface shipping. At the lower acoustic frequencies that increasingly dominate submarine detection, shipping interference represents the primary noise background limiting the performance of existing sonar systems in littoral areas. Precise notching of shipping interference could result in net system performance gains of 10-20 dB, and the algorithms and array geometries used to accomplish this will dictate future tactical sonar designs. A data-driven program of algorithmic development and performance demonstration will be conducted.

(U) The Loki program has two major elements: The Vortex Combustor Development and the Loki Systems Development Programs. These will investigate revolutionary technologies assessed to have high military payoff into coherent functional technology prototypes. Included in these programs are: 1) the development of an energy-dense air dependent underwater power source program as a potential propulsion system for an underwater fighter, and 2) the supporting systems development necessary for the operational viability of a future underwater fighter. Such an underwater vehicle would have the potential to revolutionize military and commercial undersea operations and the operational agility of maritime operations in the littoral. Specific sensor, payload, structural materials, and propulsion concepts, generated in part under the Submarine Payloads and Sensors Program (PE 0602702E, Project TT 03) and the Future Submarine Payloads program in this project will also be investigated for possible implementation in both the Vortex Combustor Development Program and the Loki Systems Development Program.

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(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Undersea Littoral Warfare (ULW). ($19.925 Million)
  – Conducted final NetSAT operational demonstration.
  – Continued development of adaptive processing algorithms for advanced surface shipping interference rejection.
  – Commenced development of noise-rejection algorithms exploiting external information.
  – Conducted preliminary Robust Passive Sonar (RPS) performance assessment using existing datasets.
  – Created baseline integrated RPS interference rejection processing stream.

- Buoyant Cable Array Antenna (BCAA). ($4.065 Million)
  – Completed algorithm and software development for space-time adaptive communications link processor.
  – Completed design of BCAA prototype antenna; conducted critical design review.
  – Fabricated BCAA prototype antenna.

- Future Submarine Payloads Program. ($1.300 Million)
  – Commenced conceptual designs for future payloads.
  – Transferred findings for use by the Loki program in FY 2002.

(U) FY 2002 Plans:

- Buoyant Cable Array Antenna (BCAA). ($10.277 Million)
  – Complete at-sea technical validation of BCAA prototype from surface platform.
  – Conduct operational demonstration of BCAA prototype from submarine.
  – Transition BCAA technology to Navy for follow-on development.

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- Robust Passive Sonar (RPS). ($21.220 Million)
  - Conduct initial at-sea collection of high quality mobile multi-line array acoustic and ancillary data.
  - Initiate development of end-to-end prototype signal processing architecture and algorithms for advanced surface shipping interference rejection, extended target detection and external information exploitation.
  - Conduct initial performance assessment based on collected data.
  - Conduct preliminary sizing for real-time processing system.
  - Initiate system trade studies for alternative acoustic aperture concepts.

- Vortex Combustor (VC). ($5.000 Million)
  - Conduct analysis and develop detailed design.
  - Fabricate test units.
  - Develop supporting fuel feed system.
  - Develop start and restart system.
  - Conduct supporting engineering studies.
  - Conduct preliminary tests.

(U) **<u>FY 2003 Plans:</u>**

- Robust Passive Sonar (RPS). ($17.000 Million)
  - Complete initial development of end-to-end prototype signal processing architecture and algorithms.
  - Conduct non real-time performance assessment using RPS sea-test data.
  - Initiate real-time processing architecture and algorithm development.
  - Initiate planning of real-time at-sea system demonstration.
  - Continue system trade studies for alternative acoustic aperture concepts.

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- Vortex Combustor (VC). ($6.000 Million)
  – Develop control system.
  – Conduct testing of the control, start, and restart systems.
  – Demonstrate submerged light-off and operation.
  – Verify VC combustion at various feed rates.
  – Demonstrate VC restart submerged after loss of combustion.
  – Demonstrate sustained operation.

- Loki Systems Development. ($4.000 Million)
  – Conduct concept of operations and military utility studies.
  – Initiate structural, material and architectural trade studies, including:
    -- Hydrodynamic performance modeling.
    -- System structural materials explorations.
    -- Advanced personnel pod design.
  – Initiate sensor guidance and control design studies.
    -- Simulation modeling of high agility, full speed control authority.
    -- Concept development of autonomous control systems.

- Undersea Littoral Warfare (ULW). ($6.000 Million)
  – Investigate technologies for classification and identification of buried mines and other underwater objects in the littoral.
  – Assess technologies for locating and tracking maritime targets of interest.
  – Pursue novel and innovative acoustic array technologies.
  – Investigate unique weapons payload concepts for potential deployment on submarines and other undersea vehicles.
  – Conduct conceptual design studies for small, autonomous, undersea vehicles.

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

	FY2001	FY 2002	FY 2003
FY02 Amended President's Budget	27.937	41.497	31.896
Current Budget	25.290	36.497	33.000

(U) Change Summary Explanation:

FY 2001 Decrease reflects the SBIR reprogramming and the transfer of funding for the Counter Proliferation Support Program to WHS.

FY 2002 Decrease reflects program repricing and congressional reductions.

FY 2003 Increase reflects funds to continue the Vortex Combustor program.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Undersea Littoral Warfare (ULW):	
Apr 02	Conduct SAS data collection exercises.
May 02	Report on innovative undersea vehicle technologies.
Oct 02	Report on buried mine detection.
FY03	Determine viable technologies and concepts for future development.
Buoyant Cable Array Antenna (BCAA):	
Jun 02	BCAA multi-element antenna prototype system complete.
Aug 02	Conduct surface ship system test.

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Nov 02 Conduct submarine system demonstration.

Robust Passive Sonar (RPS):
Mar 02 Complete Initial data collection field exercise.
Apr 03 Demonstrate non real-time end-to-end system processing.

Vortex Combustor (VC) Demonstration Program:
Aug 02 Fabricate VC test units.
Sep 02 Fuel feed system design, fabrication, and testing complete.
Nov 02 Commence exploratory system performance testing.
Mar 03 Complete exploratory system performance testing.

Loki System Development:
Feb 03 Conduct concept of operations and military utility studies
Jun 03 Initiate structural, material and architectural trade studies, including:
- Hydrodynamic performance modeling
- System structural materials explorations
- Advanced personnel pod design

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	130.610	153.067	162.100	121.407	73.561	64.553	66.260	Continuing	Continuing
Rapid Strike Force Technology LNW-01	27.817	14.651	9.000	23.719	23.794	29.761	31.507	Continuing	Continuing
Small Unit Operations LNW-02	41.205	23.216	25.000	34.688	34.767	34.792	34.753	Continuing	Continuing
Future Combat Systems LNW-03	61.588	115.200	128.100	63.000	15.000	0.000	0.000	0.000	N/A

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

(U) This program element is budgeted in the Advanced Technology Development Budget Activity because it is developing and demonstrating the concepts and technologies that will address the mission requirements of the 21st Century land warrior. Three broad efforts are being pursued in support of this objective: Rapid Strike Force Technology, Small Unit Operations and Future Combat Systems.

(U) The emerging U.S. vision of future land warfare places strong emphasis on technology supporting early entry of light, efficient land forces. The Rapid Strike Force Technology project is developing the technologies that enable mobile and survivable systems for efficient command and control, mobility, surveillance, targeting and reconnaissance, which are important aspects of an early-entry capability. The primary thrusts of this project include: 1) the Reconnaissance, Surveillance and Targeting Vehicle (RST-V) program that will design, develop, test and transition a minimum of four hybrid electric drive, lightweight, highly maneuverable advanced technology demonstrator vehicles to the Services; 2) the Solar Blind Detectors program that will develop technologies to enhance the survivability of mobile ground vehicles against the threat of advanced tactical guided missiles; 3) the Tactical Mobile Robotics (TMR) program that will develop mobile robotic technologies that will enable land forces to dominate battlespace using individual, or teams of, mobile robots in complex terrain; and 4) the Metal Storm program that will develop a system to pack, transport and fire at variable sequence rates.

(U) The goal of the Small Unit Operations project is to develop critical technologies that will enable dispersed units to effectively perform warfighting operations at varying locations. The Services are pursuing new tactical concepts for employing small, easily deployed units as an

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early entry force to address future contingencies. Their objective is to enable these forces to quickly control a large battlespace with dispersed forces, control the operational tempo, engage enemy targets with remote fire and operate effectively across the spectrum of conflict in severe communications environments. These dismounted forces must be self-sufficient, capable of operating for several days and be sufficiently lean to be quickly inserted anywhere in the world.

(U) The U.S. Military requires flexible, effective and efficient multi-mission forces capable of projecting overwhelming military power worldwide. This force must ultimately provide our national leaders with increased options when responding to potential crises and conflicts. To satisfy this requirement, the joint Army/DARPA Future Combat Systems (FCS) program was developed to provide enhancements in land force lethality, protection, mobility, deployability, sustainability, and command and control capabilities. The FCS program will develop network centric concepts for a multi-mission combat system that will be overwhelmingly lethal, strategically deployable, self-sustaining and highly survivable in combat through the use of an ensemble of manned and unmanned ground and air platforms. DARPA studies identified six key areas where technology development is needed to support the overall FCS system of systems design: robotic perception, unmanned ground combat vehicles, maneuver command control and communication (C^3), beyond line of sight fires, organic all weather targeting air vehicles and advanced laser radar sensor systems.

(U) Program Change Summary: (*In Millions*)	**FY 2001**	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	129.025	153.067	182.100
Current Budget	130.610	153.067	162.100

(U) Change Summary Explanation:

FY 2001 Increase reflects minor program repricing.

FY 2003 Decrease reflects completion of the situational awareness and urban robotics programs, and reprioritization of agency requirements.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Rapid Strike Force Technology LNW-01	27.817	14.651	9.000	23.719	23.794	29.761	31.507	Continuing	Continuing

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

(U) The emerging U.S. vision of future land warfare places strong emphasis on technology supporting early entry of light, efficient land forces. This project is developing technologies that enable mobile and survivable systems for efficient command and control, mobility, surveillance, targeting and reconnaissance, which are important aspects of an early-entry capability. The project consists of: Reconnaissance, Surveillance and Targeting Vehicle (RST-V); Tactical Mobile Robotics (TMR); Solar Blind Detectors; and Metal Storm (MS). These programs are closely coordinated with the U.S. Army, Navy and Marine Corps, and with DARPA's Small Unit Operations (LNW-02) project.

(U) The Reconnaissance, Surveillance and Targeting Vehicle (RST-V) program will design, develop, test/demonstrate and transition to the Services four hybrid electric drive, lightweight, highly maneuverable advanced technology demonstrator vehicles capable of V-22 internal transport. The vehicle will incorporate technological advancements in the areas of integrated survivability techniques and advanced suspension. The vehicle will also host integrated precision geolocation, communication and Reconnaissance, Surveillance and Targeting (RST) sensor subsystems. The RST-V platform will provide a mobile quick deployment and deep insertion capable, multi-sensor, battlespace awareness asset for small unit tactical reconnaissance teams, fire support coordinators and special reconnaissance forces. Critical components and technologies include a high efficiency, reduced signature hybrid electric propulsion system with increased fuel economy; an advanced suspension to increase cross-country speed and provide platform stabilization; an advanced integrated survivability suite; and the capability to operate in either a silent watch/silent movement or mechanical mode. The vehicle will incorporate modularized design components to allow for signature management and rapid reconfiguration for mission tailoring and multiple purpose utility. Hardware and lessons learned from this program directly support the Marine Corps-Navy Extending the Littoral Battlespace (ELB) ACTD as well as address joint U.S. Marine Corps – Special Operations Command (USMC-SOCOM) requirements for the Internally Transportable Vehicle/Light Strike Vehicle (ITV/LSV), Tactical Vehicle, Reconnaissance, Surveillance, Targeting and Acquisition (TV-RSTA) program and High Mobility Multi-purpose Wheeled Vehicle (HMMWV) upgrades. The Marine Corps will develop vehicle concepts and chassis, integrate the DARPA developed components and conduct vehicle performance tests (PE 0603640M) through participation in scheduled Advanced Warfighting Experiments (AWEs) and Advanced Concept Technology Demonstrations (ACTDs) (e.g., Capable Warrior).

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(U) The Tactical Mobile Robotics (TMR) program will develop mobile robotic technologies that will enable land forces to dominate the battlespace through employment of mobile semi-autonomous robot teams performing challenging missions in complex environments (dynamic urban areas, rugged terrain with high obstacle clutter, etc.). TMR will provide DoD organizations with a team of semi-intelligent, cooperating robot prototype platforms carrying a variety of integrated mission payloads required to conduct activities in risk intensive or inaccessible areas. Operational emphasis is on urban environments and denied areas. Specific robot technologies that will be advanced include: machine perception, autonomous operation and advanced locomotion for complex obstacle negotiation. Perception capabilities will include: (a) an on-board multi-sensor perception system capable of detecting at least 80 percent of decimeter-scale terrain hazards and at least 95 percent of meter-scale terrain hazards, both at 20 Hz; and (b) multi-source mapping algorithms capable of creating topological maps of urban structures with 90 percent accuracy. Autonomous operation capabilities will include: (a) coordination of the tactical behavior of a multi-robot team with significant command cycle reduction; and (b) traversal of rugged/complex terrain using one command per 100 meters of travel. Locomotion capabilities will feature portable (sub-meter-scale) vehicles traveling up to one meter per second over 25 cm steps and decimeter-scale rubble with open terrain sprint speeds of three meters per second.

(U) The Metal Storm program will demonstrate a revolutionary technique for firing tactically relevant projectiles at very high rates without the need for internal moving parts. The elimination of moving parts from the system should significantly reduce production and operation and support costs. It will also decrease the level of maintenance required in the field. The hardstand firing tests and demonstrations should set the stage for any service to scale and/or customize the technology for any number of current and future applications (vehicle self-defense, anti-personnel landmine replacement, ship self-defense, anti-materiel sniper rifles, etc). This effort utilizes innovative, multi-purpose, high-pressure sabot designs and projectiles for rifled barrels and will conduct a live-fire test fixture to demonstrate the following capabilities from a tactically relevant 0.40-0.50 cal. system: 1) Electronic sequential firing of three or more projectiles from a *single* barrel with the shortest possible time interval between rounds (i.e. dependent on internal projectile velocity and barrel length, tentatively 1.5msec = 40,000 rounds per minute/barrel). 2) Every projectile from a single barrel will penetrate 25.4 mm of rolled homogenous armor (RHA) at 1000 meters (0 degrees obliquity). 3) Maximum vertical spread of 1 1/2 minute of angle at 300 and 600 meters. Studies will be conducted to explore the feasibility and applicability of Metal Strom technology to other weapon systems, including vehicle self-defense, anti-personnel landmine replacement, and a naval self-defense system. Through a Project Arrangement under the Deutsch Ayers Agreement between the U.S. and Australia, the Defence Science & Technology Office (DSTO) will perform work in the areas of scaling, modeling and simulation, and small arms live fire testing.

(U) The Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration (ACTD) program will build upon products from the MAV technology program (PE 0602702E, Project TT-07) and the Organic Air Vehicle program (Project LNW-03). It will focus on the development of MAVs to accomplish unique military missions, particularly with regard to flight operations in restricted environments. The mission areas are small

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unit reconnaissance and surveillance, and support of military operations in urban terrain. The resulting capability will be beneficial in varied warfighting environments such as complex topologies (i.e. mountainous terrain with caves), heavily forested areas/dense foliage/triple canopy jungle, confined spaces (often internal to buildings) and high concentrations of civilians where it may be critical to determine the neutral or hostile intent of a crowd. The initial MAV technology development program focused on the technologies and components required to enable flight at small scales, including flight control, power and propulsion, navigation and communications. It successfully demonstrated a new class of air vehicles, MAVs, which are at least an order of magnitude smaller (between 15 and 23 cm in diameter) than previously available flying systems. The MAV ACTD program will also leverage other DARPA technology development efforts, including advanced communications and information systems, high performance computer technology, Microelectromechanical Systems (MEMS), advanced sensors, advanced electronic packaging technologies, and lightweight, efficient high-density power sources. The primary goal of the MAV ACTD program is to further develop and integrate MAV technologies into militarily useful and affordable systems suitable for dismounted soldier, marine, and special forces missions.

(U) The Solar Blind Detectors program (formerly titled "Vehicle Self-Protection") developed an ultraviolet (UV) solar blind, solid state focal plane array to significantly enhance the survivability of mobile ground vehicles against the threat of advanced tactical guided missiles at greatly reduced cost.

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

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

- Reconnaissance, Surveillance and Targeting Vehicle (RST-V). ($6.894 Million)
  - Participated in the Marine Corps-Navy Extending the Littoral Battlespace (ELB) ACTD.
  - Demonstrated V-22 compatibility.

- Tactical Mobile Robotics (TMR). ($10.214 Million)
  - Completed initial prototype development.
  - Completed initial design of Human Robot Interface for multi-robot control, heterogeneous platform collaboration and marsupial operations.
  - Initiated tactical experiment plan with fully functional platforms to determine operational value baseline.
  - Refined collective experimentation plan.

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- Solar Blind Detectors Program. ($3.673 Million)
  - Demonstrated solar-blind detector array with 256 x 256 pixels.

- Metal Storm (MS). ($7.036 Million)
  - Performed scaling analysis of Metal Storm technology to larger calibers.
  - Completed .45-caliber smooth bore proof-of-principle barrel/ammunition design.
  - Conducted studies to explore the feasibility and applicability of Metal Storm technology to other weapon systems.

(U) **FY 2002 Plans:**

- Reconnaissance, Surveillance and Targeting Vehicle (RST-V). ($5.314 Million)
  - Integrate and demonstrate Survivability Suite.
  - Complete RST/ C^4I test.
  - Rollout vehicles 3 and 4.
  - Continue development and integration of high packaging density electronics and control technologies to include battery power conversion, thermal management, and systems control.

- Metal Storm (MS). ($5.919 Million)
  - Conduct vented bomb tests.
  - Conduct preliminary smooth bore test firings with U.S. contractor and Australian government partner.
  - Perform a series of rifled bore proof-of-principle test firings with performance increasing to the minimum time interval between rounds and 1200 m/s muzzle velocity.
  - Demonstrate a preliminary reloading concept.

- Tactical Mobile Robotics (TMR). ($3.418 Million)
  - Complete final prototype modifications.
  - Initiate full team integration including multi-modal Human Robot Interface and collaborative platform system.
  - Conduct initial collective platform experiments in unscripted tactical vignettes.

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– Initiate transition to military departments.

(U) **FY 2003 Plans:**

- Reconnaissance, Surveillance and Targeting Vehicle (RST-V). ($3.000 Million)
  – Participate in Joint C^4I Enabler Advanced Concept Technology Demonstration.
  – Integrate mission-specific equipment.
  – Conduct Limited Technical Assessment at Yuma Proving Ground.
  – Deliver vehicles 1, 2, 3, and 4.
  – Deliver final report.

- Tactical Mobile Robotics (TMR). ($1.000 Million)
  – Complete transition to the services.
  – Conduct follow-on studies for perception and route planning systems.

- Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration (ACTD). ($4.000 Million)
  – Demonstrate electric MAV in Military Operations in Urban Terrain (MOUT) exercises.
  – Conduct experiments with troops in field trials.
  – Evaluate lessons learned and design of internal combustion engine powered MAV.

- Metal Storm (MS). ($1.000 Million)
  – Design and simulate high performance, multi-barrel systems for launching 40-50 millimeter supersonic projectiles.
  – Conduct testing and assessment of critical system components.

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(U) **Other Program Funding Summary Cost:** *(In Millions)*

	FY 2001	**FY 2002**	**FY 2003**
Reconnaissance, Surveillance and Targeting Vehicle (RST-V)	2.750	2.990	1.000
PE 0603640M Marine Corps Advanced Technology Demonstration			
Micro Air Vehicles ACTD			
PE 0603001A Army	0.0	10.0	0.0
PE 0603750D OSD	0.0	1.0	3.5

(U) **Schedule Profile:**

Plan	Milestones
Metal Storm (MS):	
May 02	MS: Demonstrate single-barrel electronic sniper rifle.
Mar 03	MS: Multi-barrel electronic sniper rifle Critical Design Review.
Reconnaissance, Surveillance and Targeting Vehicle (RST-V):	
Mar 02	RST-V: Integrate and demonstrate Survivability Suite.
Jun 03	RST-V: Participate in Joint C^4I Enabler Advanced Concept Technology Demonstration.
Aug 03	RST-V: Final Report.
Sep 03	RST-V: Deliver Vehicles 1, 2, 3, and 4.
Tactical Mobile Robotics (TMR):	
Dec 02	TMR: Complete transition and technology to military services.
Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration (ACTD):	
Jul 03	Demonstrate electric MAV in military operations in urban terrain exercises.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Small Unit Operations LNW-02	41.205	23.216	25.000	34.688	34.767	34.792	34.753	Continuing	Continuing

(U) Mission Description:

(U) The Services are pursuing new tactical concepts for employing small, easily deployed units as an early entry force to address future contingencies. Their objective is to enable these forces to quickly control a large battlespace with dispersed forces, control the operational tempo, engage enemy targets with remote fire and operate effectively across the spectrum of conflict in severe communications environments. These dismounted forces must be self-sufficient, capable of operating for several days and be sufficiently lean to be quickly inserted anywhere in the world.

(U) Superb situational awareness is critical to the combat effectiveness and survivability of such forces. Each small team must constantly know where it is, where the other teams are and where the enemy and any other threats are located. The Services are developing lightweight communication and Global Positioning Systems (GPS) dependent geo-positioning systems packaged into fielded capabilities such as the Land Warrior System. In addition, advanced standoff sensor systems such as Predator and Global Hawk have been developed to monitor the enemy's movements and characterize the battlespace. Under current configurations, these capabilities will greatly improve the combat effectiveness of small dismounted forces, but will be limited to operations in open areas under benign conditions. Current communications, navigation and sensor technologies are poorly configured to operate in urban areas (outside or inside buildings), in jungles, forests or mountainous terrain. Communications technology is susceptible to enemy jamming or unintentional radio interference and is not covert to intelligence operations. Extant sensors and exploitation capabilities are limited to broad area surveillance of vehicles and facilities; data is not mined and distributed to forces at the lowest echelon.

(U) The objective of the Small Unit Operations Project is to develop critical technologies that will enable small dismounted forces to effectively fight anywhere, anytime. The technology needs are: semi-automated maneuver and strike/fire planning and re-planning that can be employed by commanders who are physically separated but need to be virtually collocated; automated aggregration and mining of information sources to provide a “bubble” of awareness over each warrior and team describing the relevant situation; accurate geographic position estimation, other than GPS, which works in all environments; and radio links and self-forming ad hoc networked communications that “glue” the components together, operate in any environment, are covert and resistant to interference. In addition, these technologies must not significantly increase the dismounted force’s mass and power burden. The programs that make up this project include the Situational Awareness System (SAS), Tactical Sensors, Optical Tags, Wolfpack, Advanced Sensing Technologies and Robotics.

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(U) The Situational Awareness System (SAS) will integrate a variety of communications, navigation and data processing technologies into an eventual 1 kg module (plus 0.5 kg per day for the power source) worn by the individual warrior. The radio frequency module will be interoperable with the Army Land Warrior equipment and provide much greater functionality. The warrior module will provide the communications and computing power to fully interconnect the dismounted force and enable situation awareness information to be distributed, as well as support continuous planning and combat execution. This program will investigate the critical SAS performance parameters with in-depth experiments. It will provide user-centered design input for developers and provide an independent assessment of the SAS design. The experiments will be focused to evaluate the sensor employment, validate network robustness and reliability, and conduct a scenario-focused evaluation of geolocation and navigation requirements in urban, forested and mountainous terrain. Specialized tools will be developed to generate scenario-synchronized data for development and evaluation of the SAS functions. The program will coordinate the use of testing infrastructure to conduct evaluations and assessment and will employ a combination of military and technical subject matter experts, computer modeling and simulation tools, and laboratory and field exercises to provide independent validation of the SAS functionality.

(U) The Tactical Sensors program will develop unattended ground sensors, planning tools, deployment mechanisms, and the command and control that will provide the warfighter a capability to detect, track and classify mobile tactical targets. These systems provide a local, in-situ sensing capability deep in denied areas. Information provided by these systems can be fused with other assets to enhance the aggregate situational awareness of U.S. forces. Applications include surveillance, cueing, precision targeting, intelligence and battle damage assessment with respect to time critical mobile targets.

(U) The Optical Tags program will investigate optical technologies and innovative design and fabrication techniques for kilometer-range optical tag systems, which provide a quantum leap in tactics and operations in a wide variety of applications. The Optical Tags program will develop validated models to predict system performance in support of a selected set of applications for technology demonstration. The program will select a relatively mature application, such as marking or tagging, and a relatively immature application, such as precision strike. The applications will be selected based on their operational significance and user input. The Optical Tags program will perform system engineering to develop systems performance requirements for the applications and will demonstrate the systems in meaningful warfighter experiments.

(U) The Wolfpack program will develop technologies that would enable the U.S. to deny the enemy use of radio communications and radars throughout the battlespace. This will culminate in a networked system of autonomous, ground-based monitors/jammers linked together to cooperate and avoid disruption of friendly military and protected commercial radio communications and radars. The specific technologies to be developed include: (1) high efficiency sub-resonant antennas, (2) networking algorithms to allow coordinated access to the spectrum by communicators,

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jammers and SIGINT systems, (3) methods to easily deploy the systems in RF advantaged sites, and (4) algorithms to rapidly and autonomously detect, classify, identify and jam target signals with low power electronics.

(U) The Advanced Sensing Technologies program will develop a completely new class of sensors for military surveillance and targeting applications. These sensors will provide surveillance, target detection, tracking, classification, cueing and bomb damage assessments at distances much greater than current capabilities. The sensors will use recent technical breakthroughs to exploit vulnerabilities and permit access to the target signatures. This program completed in FY 2001.

(U) While great progress has been made in robotic technology, practical military applications has been limited to specific niches such as explosive ordnance demolition including mine clearing. For the biggest military impact, general-purpose robots are needed. The Robotics effort will focus on using robotic technology to impact operations in urban areas: the insides of buildings, intricate distribution channels including sewers, sub-urban terrain of all types, and roads. This environment poses many difficulties for today's military and offers the hardest challenges for mobility, perception, and manipulation. This program will also focus on aspects of biological inspiration for generating new robotic platforms with maneuvering ability, sensing and autonomy compatible with combat, especially in urban terrains.

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

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

- Situational Awareness System. ($16.056 Million)
  - Completed fabrication of Individual Warfighting System Situational Awareness System (IWSAS), Warfighter Tactical Associate (WTA) Mobile and Base, tactical sensors and tactical relays for test.
  - Integrated IWSAS, WTA-Mobile and Base with external legacy communications, data and sensor equipment.
  - Tested integrated system and conducted performance assessment of final Phase 3 design; measured IWSAS, WTA and Relay Radio Frequency (RF) propagation in multipath, jamming and open environments.
  - Completed development of detailed demonstration scenarios to test and evaluate performance under operational conditions.

- Tactical Sensors. ($11.702 Million)
  - Continued development of internetted remote control sensors and fusion algorithms to detect, localize and characterize targets.

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- Continued development of surveillance and targeting sensor systems for dispersed operations.

- Optical Tags. ($3.886 Million)
  - Fabricated appliqué-based optical tag with appropriate spectral response and demonstrated that it achieves desired performance over kilometer-class range.
  - Developed performance model in the mature (e.g. ground-to-ground) application, for both appliqué and random matrix tags, and predicted performance over a wide range of scenarios.

- Advanced Sensing Technologies. ($2.909 Million)
  - Completed brassboard and initiated fieldable sensor development.

- Wolfpack. ($6.652 Million)
  - Initiated system design and performance analysis.
  - Conducted analysis for the applicability of distributed ground jammers to attack surface to air radar systems.
  - Initiated development of networked, distributed jamming enabling technologies.

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

- Situational Awareness System. ($7.115 Million)
  - Complete prototypes.
  - Develop training materials and conduct soldier training for field demonstration.
  - Conduct field demonstration to verify communications performance in urban, forested and mountainous terrain when operated by warfighters. Show the use of multiple organic sensors being operated by battalion and below warfighters.

- Optical Tags. ($0.610 Million)
  - Design and test portable interrogator and detector system to support testing of the tags at ranges up to 1 Km in field environments.
  - Develop and test remote tag emplacement method.

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- Tactical Sensors. ($3.918 Million)
  - Complete development and field-test internetted remote control sensors to detect, localize and characterize targets.
  - Develop prototype planning tools and complete designs of deployment mechanisms.
  - Interface to operational command and control console.

- Wolfpack. ($11.073 Million)
  - Continue development of enabling technologies.
  - Complete system design and performance analysis.

- Robotics. ($0.500 Million)
  - Demonstrate mobility of legged vehicles superior to those of tracked and wheeled vehicles.
  - Demonstrate sensor systems based on biomimetic principles compatible with operations in urban terrain.

(U) **FY 2003 Plans:**

- Wolfpack. ($19.000 Million)
  - Complete enabling technology development.
  - Verify low duty cycle, low power jamming techniques with benchtop experiments.
  - Construct and lab test brassboard-jamming subsystems.
  - Conduct limited lab tests using brassboard equipment to attack several legacy type communication systems.

- Robotics. ($1.000 Million)
  - Develop concepts for autonomous control of robotic platforms.
  - Integrate mobility and sensor concepts into taskable and/or autonomous platforms.

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- Conduct field-testing of unmanned systems based on results generated in FY 2002 to validate models and update accordingly.

- Situational Awareness System. ($1.500 Million)
  - Complete transition to U.S. Army, U.S. Marine Corps and United States Special Operations Command (USSOCOM).

- Optical Tags. ($1.500 Million)
  - Develop an eye safe tagging and interrogator system.
  - Improve the response efficiency of the tags.
  - Demonstrate system operation at ranges up to 1 Km.

- Tactical Sensors. ($2.000 Million)
  - Fabricate and demonstrate four unattended ground sensor clusters in an end-to-end, turnkey system for Volcano system launch from a Blackhawk helicopter.
  - Demonstrate extremely high confidence levels of time critical target classification and precision target tracking.
  - Design, prototype, and evaluate the field performance of Volcano-compatible sensor nodes for detection and tracking of dismounted targets.
  - Conduct preliminary designs and concepts for the emplacement and utilization of nodes in urban environments.

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

	FY 2001	FY 2002	FY 2003
Wolfpack, Geolocation and Disruption of Terrorist Communications Defense Emergency Response Fund (DERF)	0.000	0.000	(8.000)

This emergency supplemental effort to the WolfPack program will enable near real time geolocation of terrorist radio communications using both military and commercial systems, and surgically deny usage of those communication systems through the use of a precise,

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coordinated response. As a Suppression of Enemy Air Defense asset, close proximity WolfPack systems will also permit non-lethal disruption of enemy radar systems, including possible terrorist reuse of civilian platforms.

(U) Schedule Profile:

Plan	Milestones
Situational Awareness System:	
Jun 02	SAS prototypes fabricated.
Sep 02	SAS final demonstration.
Tactical Sensors:	
Jul 02	Participate in field exercise.
Robotics:	
Sep 03	Field test of unmanned systems.
Wolfpack:	
May 02	System Design/Technology Assessment Review (Phase III).
Nov 02	Initial Enabling Technology Demonstrations (Phase II).
Sep 03	Final Enabling Technology Performance Review (Phase II).
Jun 04	Subsystem field-testing complete (Phase IV).
Optical Tags:	
May 02	Increased Range Field Demonstration.
Sep 02	System Design Review/Technology Assessment.
May 03	Demonstrate Eye Safe Tagging System.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development					R-1 ITEM NOMENCLATURE Land Warfare Technology PE 0603764E, Project LNW-03				
COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Future Combat Systems LNW-03	61.588	115.200	128.100	63.000	15.000	0.000	0.000	0.000	N/A

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

(U) The U.S. Military requires flexible, effective and efficient multi-mission forces capable of projecting overwhelming military power worldwide. This force must ultimately provide our national leaders with increased options when responding to potential crises and conflicts. To satisfy this requirement, the joint Army/DARPA Future Combat Systems (FCS) program was developed to provide enhancements in land force lethality, protection, mobility, deployability, sustainability, and command and control capabilities.

(U) The FCS program will develop network centric concepts for a multi-mission combat system that will be overwhelmingly lethal, strategically deployable, self-sustaining and highly survivable in combat through the use of an ensemble of manned and unmanned ground and air platforms. The goal of the FCS program is to design such an ensemble that strikes an optimum balance between critical performance factors, including ground platform strategic, operational and tactical mobility; lethality; survivability; and sustainability. This system of systems design will be accomplished by using modeling, simulation and experimentation. The FCS unit will be capable of adjusting to a changing set of missions, ranging from warfighting to peacekeeping, as the deployment unfolds. An FCS-equipped force will be capable of providing mobile-networked command, control, communication and computer (C^4) functionalities; autonomous robotic systems; precision direct and indirect fires; airborne and ground organic sensor platforms; and adverse-weather reconnaissance, surveillance, targeting and acquisition (RSTA).

(U) DARPA studies identified six key areas where technology development is needed to support the overall FCS system of systems design: robotic perception, unmanned ground combat vehicles, maneuver command control and communication (C^3), beyond line of sight fires, organic all weather targeting air vehicles and advanced laser radar sensors.

(U) The Perception for Off-road Robotics (PerceptOR) program will identify and develop revolutionary unmanned vehicle perception prototypes. These perception systems will be flexible enough to operate in off-road environments and will be backed by extensive experimental test data in a variety of operationally relevant terrain and weather conditions. The resulting technology will be applicable to a variety of combat roles and will enable greater confidence in postulating the conditions under which unmanned off-road robotics should be used. The use of advanced remote imagery and small numbers of collective robots will be included in the approaches taken.

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(U) The Unmanned Ground Combat Vehicle program will develop vehicle prototypes exhibiting advanced performance in endurance, obstacle negotiation, and transportability (small size) based on novel designs unrestrained by the need to accommodate human crews. These prototypes may include unique mobility configurations (traditional wheeled/tracked to organic-mimicking, i.e. walking/crawling), exceptional drivetrains, advanced structures/composites, terrain/soil analysis, sensory exploitation and interaction with robotic control architectures.

(U) The Maneuver C^3 program will develop robust, assured and potentially high data rate connectivity for the Future Combat Systems (FCS) elements along with a command and control architecture to reduce the number of forward deployed Command and Control (C^2) operators. The communications component will develop an integrated architecture that provides for a seamless transition from line-of-sight to non-line-of-sight communications. To enable this functionality, development of new secure waveforms, directional antennas and mobile ad hoc networks will be initiated. The C^2 component will directly leverage the Army's investment in the automation of the Battlefield Functional Areas within the Army Battle Command System (ABCS). Because of the multitude of single aspect systems that feed information in ABCS, large amounts of data are made available to the commander, thus requiring a much larger staff of operators and workstation analysts to complete the fusion function of battlefield data into information for the commander to make decisions. Future operations involving FCS technologies and operational capabilities cannot be restricted by a less responsive C^2 architecture and large support staffs. The FCS C^2 program will attempt to integrate and compress selected Battlefield Functional Area functions in a scaled architecture to support the FCS Unit Cell operations. Through the use of advanced information technologies and knowledge base engineering, this program will attempt to develop an advanced method of command and control, which integrates the previous stove-piped Battlefield Functional Areas (BFAs) into a single integrated information environment (Commander's Support Environment, CSE) which will support the command and control of manned and unmanned systems. The technical approach is to use IT to facilitate the synthesis of information presented to an FCS Commander by moving as much of the information/data integration to a HW/SW environment thus allowing the Commander and Battle Managers to leverage existing operational opportunities by focusing on fewer unknowns, clearly visualize current and future operational end states and dictate the tempo of operations within a variety of environments, while being supported by a significantly reduced staff. The true compression and integration of these functions would provide the FCS commander with information for rapid decision making vice numerous data streams requiring analysis by a large battle staff. The compression of these selected functions would enable a reduction of personnel in the Unit Cell C^2 element, and facilitate anticipatory planning and adaptive execution by the FCS Commander. A top level C^2 architecture (systems and operational) will be developed and validation of the architecture and assessment of performance (e.g., command latencies) will be achieved by conducting a series of four experiments within a simulated environment.

(U) The Netfires (formerly Advanced Fire Support System) program will develop and test a containerized, platform-independent multi-mission weapon concept as an enabling technology element for FCS. NetFires will provide rapid response and lethality in packages requiring

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significantly fewer personnel, decreased logistical support and lower life-cycle costs, while increasing survivability compared to current direct fire gun and missile artillery. NetFires will allow FCS to defeat all known threats, will be air deployable in C-130 (and smaller) aircraft, and will enhance the situation awareness and survivability of FCS by providing standoff target acquisition and extended-range, non-line-of-sight engagements. The program will develop and demonstrate a highly flexible modular, multimission precision missile and a loitering attack missile that can be remotely commanded. Both missile types will have a self-locating launcher and a command and control system compatible with FCS.

(U) The Organic All-Weather Targeting Air Vehicle program provides FCS direct and indirect weapons system targeting under all operating conditions at the small unit level. The approach is to develop all weather vehicles for operation at two tiers; an upper tier for wide area coverage and a lower tier that allows a close-up view for positive target identification. For the higher tier, the A160 Vertical Take Off and Landing (VTOL) Unmanned Air Vehicle (UAV) program will develop a vehicle for carrying out airborne surveillance and targeting against ground targets. The A160 vehicle will further provide an airborne communications/data link relay between the various ground components and the command nodes and SATCOMs. In addition, the A160 will deploy unmanned ground sensors (UGS), unmanned ground vehicles (UGV), and Micro Air Vehicles (MAV) and provide a data link between them and the C^2 components. For the lower tier, the Organic Air Vehicle (OAV) program will develop a small (<75 lbs) air vehicle that can fly autonomously in adverse weather. It will leverage DARPA Micro Air Vehicle program technologies and design a ducted fan vehicle that is scalable between 9 and 29 inch outside diameter to accommodate varying missions and payloads.

(U) The Jigsaw program will develop advanced laser radar (LADAR) sensor systems and technologies for day/night target identification and verification in stressing environments. Stressing environments include targets hidden by foliage and camouflage, and targets in urban settings, such as alleyways and alcoves. The sensor systems and technologies developed under this project will support the needs of FCS and will enable human observers to perform combat identification reliably and confidently through a visualization of the target scene by the LADAR sensor(s).

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

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

- FCS Concept Development. ($15.288 Million)
  - Identified key technologies, technology tradeoffs, and technology roadmaps.
  - Established program Integrated Data Environment (IDE).
  - Developed detailed Program Acquisition Strategy and evaluated alternative strategies to accelerate system fielding.

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– Initiated Government Experiment activities to identify critical questions and understand the impacts of selected solutions.
– Defined program metrics and structure modeling and simulation activities to address those metrics.
– Developed baseline operational documentation.
– Began to identify the role of FCS as it relates to the Army's vision of an Objective Force.

- FCS Supporting Technologies. ($46.300 Million)

– PerceptOR.
- - Developed unmanned maneuver algorithms that use a combination of on-board and off-board sensors and terrain data to maximize the level of autonomous operation.
- - Developed four surrogate perception prototypes for testing in FY 2002.
- - Performed high resolution Lidar, visible, and multi-spectral imagery data collection from air platform over terrain containing several forms of forest, meadow, and pond areas in both winter and summer vegetation conditions.
- - Analyzed these data sets to determine what size and type of features could be automatically detected for ground vehicle navigation improvement.

– Unmanned Ground Combat Vehicle (UGCV).
- - Completed 11 Preliminary Designs for UGCV prototypes including finite element structural analysis, preliminary obstacle negotiation simulations, and endurance calculations to support the primary program metrics.
- - Highlighted critical technologies for achieving higher mobility and endurance in configurations associated with payloads of both 150 kg (~330 lbs) and 1500 kg (3300 lbs) as representative of reconnaissance and weapons carrier vehicles respectively.
- - Initiated procurement of Long Lead hardware for Phase 1B testing in FY 2002.
- - Selected 4 designs for continued Critical Subsystem Testing and Detail Prototype Design (Phase 1B) in FY02.

– Maneuver C^3.
- - Developed top-level architecture (operational and systems) for the FCS Unit Cell.
- - Defined and initiated the development of the FCS Unit Cell Commander's Support Environment (CSE).
- - Established a C^2 laboratory environment to conduct applied research in C^2 for FCS.
- - Initiated the design of the C^2 architecture for the lowest, integrated FCS echelon ("unit cell").
- - Conducted the first of four experiments in December 2001.
- - Developed simulations for the integrated "unit cell" C^2 architecture.
- - Examined potential wireless communications network architectures.

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- - Developed technologies for assured communications in a hostile environment using novel waveforms and beam steering antennas for low probability of detection and anti-jam.

– Netfires.
- - Continued system hardware and software development for missiles, container/launchers and command/control units.
- - Completed critical component demonstrations for motor, seeker, navigation and data link.
- - Planned and initiated preparations for flight-test demonstrations.

– Organic All-Weather Targeting Vehicles.
- - Determined requirements for organic air vehicles to be used as sensor platforms.
- - Developed air vehicles capable of operating in adverse weather.
  - Defined A160 systems for operating in adverse environments: rain, icing, sand/dust, salt spray, and turbulence.
  - Defined A160 Synthetic Aperture Radar/Moving Target Indicator (SAR/MTI) radar sensors and designed Radar/A160 interfaces.
  - Initiated ground and flight test phase of A160 air vehicle AV001.
  - Designed and initiated fabrication of Organic Air Vehicle (OAV) capable of autonomous flight.
  - Conducted OAV integrated technology systems demonstration.

– Jigsaw: LADAR Sensing for Combat ID.
- - Initiated development of technology that can identify hidden targets by poking through holes in foliage and camouflage and by combining 3-D images from multiple viewpoints to "see" through partial obscuration.
- - Conducted trade studies to determine best technological approach to LADAR sensing for FCS application, including lasing, detection, and data processing.

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

- FCS Concept Development. ($30.000 Million)
  – Carryout concept and technology demonstration (CTD) to support decision for transition to System Development and Demonstration (SDD) in 2003.
  – Select single Lead Systems Integrator (LSI) to carryout CTD program in partnership with the Government.

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- FCS Supporting Technologies. ($85.200 Million)
  - PerceptOR.
    - - - Conduct perception system prototype development testing in both laboratory and field.
    - - - Conduct unrehearsed evaluation experiments on early perception system prototypes in variety of terrain and environmental conditions.
    - - - Conduct algorithm development for advanced perception behavior.
  - Unmanned Ground Combat Vehicle (UGCV).
    - - - Complete critical subsystem testing and detailed prototype designs.
    - - - Select two designs for full prototype fabrication.
    - - - Initiate prototype fabrication.
    - - - Conduct initial UGCV surrogate tests.
  - Maneuver C^3.
    - - - Validate organic, self-contained approaches versus approaches that “reachback” to other systems for C^2.
    - - - Select wireless communications network architecture(s) for implementation.
    - - - Demonstrate sub-system components for assured communications in a hostile environment using novel waveforms and beam steering antennas for low probability of detection and anti-jam.
    - - - Refine Commander’s Support Environment (CSE) and expand CSE knowledge base and collective intelligence module.
    - - - Continue to refine and expand supporting simulation.
    - - - Collect and assess the insights of human-machine interface requirements for training prototypes with the assistance of Army Research Institute.
    - - - Conduct experiments #2 and #3 in support of selected command & control functions for operations with manned/unmanned systems.
  - Netfires.
    - - - Initiate ballistic test vehicle and controlled test vehicle demonstrations.
    - - - Complete pintle motor development and testing.
  - Organic All-Weather Targeting Vehicles.
    - - - Select platform and sensory payload for detailed design and prototyping efforts.
    - - - Complete flight testing of initial sizes for OAVs.

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- - Initiate detailed design efforts for different size Organic Air Vehicle to flight demonstrate the design code and scalability of the technology.
- - Ground test A160 anti-icing systems, sand/dust/salt protection systems, and precision flight systems.
- - Integrate SAR/GMTI Radar in A160 vehicle radome.
- - Demonstrate initial Organic Air Vehicle (OAV) gust stability and inner loop control.
- - Demonstrate second-generation OAV autonomous navigation and auto-landing capabilities.

– Jigsaw: LADAR Sensing for Combat ID.
- - Conduct preliminary design reviews for prototype LADAR sensors for airborne captive carry operation.
- - Conduct critical design reviews for alternative prototype LADAR sensors.
- - Build prototype LADAR sensors, collect data, and conduct experiments.

(U) <u>FY 2003 Plans:</u>

• FCS Concept Development. ($48.000 Million)
– Complete concept and technology demonstration (CTD) phase.
– Prepare for Technology Investment Decision Review.
– Transition program from concept and technology development to system design and demonstration.
– Initiate Force Development Testing and Evaluation (FDT&E) activities including limited man-in-the-loop testing.

• FCS Supporting Technologies. ($80.100 Million)
– PerceptOR.
- - Continue algorithm and supporting technology developments for unmanned maneuver.
- - Update prototype algorithms and hardware based on supporting experimentation.
- - Conduct unrehearsed field-testing of prototypes in extreme terrain and explore system implications of degraded component performance (communications constraints, sensor and other faults).

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– Unmanned Ground Combat Vehicle (UGCV).
  - - Complete UGCV prototype fabrication and rollout.
  - - Conduct initial testing of prototypes against mobility, endurance, and payload fraction metrics.
  - - Conduct resilience testing on prototypes and make reliability measurements.
  - - Update prototype hardware with late development technology and prepare for extreme testing conditions.
  - - Integrate PerceptOR technology onto a UGCV platform.

– Maneuver C^3.
  - - Complete the development of an initial FCS C^2 experimental demonstrator.
  - - Continue experiments of Unit Cell C^2 incorporating limited activities of the dismounted soldier.
  - - Document and finalize C^2 architecture for FCS unit cell.
  - - Provide an experimental test bed for future FCS developmental efforts using simulation.
  - - Demonstrate an integrated architecture that provides seamless transition from line-of-sight to non-line-of-sight communications via unmanned aerial vehicles and satellite communications.
  - - Demonstrate new secure communication waveforms and mobile ad hoc networks using directional antennas.

– Netfires.
  - - Complete controlled test vehicle demonstrations and initiate guided test vehicle demonstrations.
  - - Conduct critical design reviews.
  - - Investigate coordination of multiple Netfires missiles.

– Organic All-Weather Targeting Vehicles.
  - - Continue prototype platform development and sensory payload.
  - - Perform testing.
  - - Continue A160 anti-icing systems tests.
  - - Flight test A160 SAR/GMTI Radar.
  - - Complete A160 Satellite Communications (SATCOM) study.
  - - Complete A160 Survivability study.
  - - Complete A160 resupply study.
  - - Demonstrate third-generation Organic Air Vehicle (OAV) flight in rain, icing and adverse weather.

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- - Demonstrate OAV waypoint flight with collision avoidance in stressing environments.

– Jigsaw: LADAR Sensing for Combat ID.
  - - Conduct demonstration of Combat ID capabilities with LADAR sensing using prototype Jigsaw LADAR sensors against stressing targets.
  - - Develop a design for an objective LADAR sensor for FCS applications.

(U) **Other Program Funding Summary Cost:** *(In Millions)*

	FY 2001	FY 2002	FY 2003
PE 0602601A Combat Vehicle and Automotive Technology	7.752	19.652	0.000
PE 0603005A Combat Vehicle and Automotive Advanced Technology	5.312	87.586	122.000

(U) **Schedule Profile:**

Plan	Milestones
Feb 02	Conduct unrehearsed field-testing of robot perception systems in forest and meadow (Ft AP Hill).
Feb 02	Demonstrate mobile, wireless network operation with directional antennas below 3 GHz.
Mar 02	Complete FCS Phase I and select Lead Systems Integrator (LSI).
Mar 02	Critical design review of prototype Laser Radar (LADAR) sensors with processing method for Combat ID.
Apr 02	NetFires ballistic test vehicle firings.
Apr 02	Sensor breadboard testing (laboratory).
May 02	Complete UGCV integrated testbed detailed design and procure long lead items for fabrication.
May 02	Experiment #2 FCS C^2 “See, Move, Strike”.
May 02	Conduct unrehearsed field-testing in desert conditions for PreceptOR (Yuma).
Jun 02	Complete A160 AV003.
Jun 02	Preliminary data collections using prototype Jigsaw LADAR sensors.
Aug 02	Conduct unrehearsed field testing in mountain terrain for PreceptOR (California)
Aug 02	Complete UGCV technology testbed data collection.

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Sep 02	Demonstrate mobile, wireless network operation with directional antennas below and above 3 GHz.
Oct 02	SAR/GMTI Radar first flight on A160.
Oct 02	Experiment #3 FCS C^2 "See, Move, Strike, Sustain" (including limited functionality sub experiments of Future Warrior).
Nov 02	Validate OAV adverse weather flight capability with 2 different sized vehicles to demonstrate scalability.
Nov 02	Conduct unrehearsed field testing in wet terrain of PerceptOR (Florida)
Dec 02	Demonstration of capability to ID targets using LADAR data from prototype Jigsaw sensors, combining data from multiple views.
Dec 02	Rollout UGCV integrated prototypes.
Jan 03	Anti-icing system first flight on A160.
Jan 03	Demonstrate OAV waypoint flight with collision avoidance.
Jan 03	Demonstrate initial performance of UGCV Prototypes against obstacles and endurance goals.
Feb 03	Demonstrate assured, seamless, mobile, wireless network operation with directional antennas at multiple bands in a relevant operational and threat environment.
Feb 03	Experiment #4.
Feb 03	Conduct unrehearsed field-testing of improved PerceptOR perception system prototypes in extreme terrain and degraded conditions.
Mar 03	Army decision on FCS technology readiness levels.
May 03	Complete FCS Concept Design Preliminary Design Review.
Jun 03	Initiate FCS Detailed Design.
Jul 03	Sensor field tests.
Aug 03	Critical design review of objective LADAR sensors for FCS applications.
Sep 03	Complete initial Unmanned Ground Combat Vehicle (UGCV) contractor testing of all integrated testbeds to prepare for government testing in complete FCS environment.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA6 Management Support	R-1 ITEM NOMENCLATURE Management Headquarters (Research and Development) PE 0605898E, Project MH-01, R-1 #121

COST *(In Millions)*	FY 2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	32.544	36.102	43.572	46.124	48.566	48.611	48.259	Continuing	Continuing
Management Headquarters (R&D) MH-01	32.544	36.102	43.572	46.124	48.566	48.611	48.259	Continuing	Continuing

(U) Mission Description:

(U) This program element is budgeted in the Management Support Budget Activity because it provides funding for the administrative support costs of the Defense Advanced Research Projects Agency. The funds provide personnel compensation for civilians as well as costs for building rent, physical and information security, travel, supplies and equipment, communications, printing and reproduction.

(U) The FY 2001 Defense Authorization Act approved hiring 20 additional Section 1101 experimental hires in addition to the 20 hire approved in prior legislation. The salary, benefits and bonuses for those individuals (totaling approximately $150,000 per employee) are included in the Management Headquarters PE. Those employees will replace departing Intergovernmental Personnel Act employees whose salary costs were reimbursed to their respective host organizations using program (Budget Activity 1 - 3) funds.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Management Headquarters. ($ 32.544 Million)
  - DARPA continued to fund civilian direct-hires, both career and Section 1101 employees, and administrative support costs. Expanded Departmental and Federal physical and information security requirements and pay raise requirements were also funded.

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APPROPRIATION/BUDGET ACTIVITY **Error! Reference source not found.** BA6 Management Support	R-1 ITEM NOMENCLATURE Management Headquarters PE 0605898E, R-1 #121

(U) **FY 2002 Plans:**

- Management Headquarters. ($ 36.102 Million)
  - DARPA will continue to fund civilian direct-hires, Section 1101 employees and administrative support costs. Anticipated pay raise requirements are also funded. Salary, benefits and bonus requirements for an additional 20 Section 1101 employees authorized by the FY 2001 Defense Authorization Act partially are included, reflecting gradual phase-in of these employees during FY 2002.

(U) **FY 2003 Plans:**

- Management Headquarters. ($ 43.572 Million)
  - DARPA will continue to fund civilian direct-hires, both career and Section 1101 employees, and administrative support costs. Anticipated pay raise requirements are also funded. Full compensation for all 40 sections 1101 hires is reflected.
  - A substantial increase in security-related costs are budgeted, including a major expansion of access controls, uniformed guards, and building security upgrades.
  - CFO act compliance costs are funded.

(U)

Program Change Summary: (*In Millions*)	**FY2001**	**FY 2002**	**FY 2003**
FY02 Amended President's Budget	32.379	36.937	38.414
Current Budget	32.544	36.102	43.572

(U) **Change Summary Explanation:**

FY 2001	Increase reflects minor program repricing.
FY 2002	Decrease reflects congressional program reduction.
FY 2003	Increase fully reflects the addition of 20 Section 1101 experimental hires, pay raises, the costs associated with the CFO Act compliance, and major security upgrades to counter any terrorist threats.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA66 Management Support	R-1 ITEM NOMENCLATURE Management Headquarters (Research and Development) PE 0605898E, R-1 #123

(U) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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