UNCLASSIFIED

Department of Defense FY 2002 Amended Budget Submission

June 2001

RESEARCH, DEVELOPMENT, TEST AND EVALUATION, DEFENSE-WIDE

Volume 1 - Defense Advanced Research Projects Agency

UNCLASSIFIED

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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NOTE: This administration has not addressed FY 2003 - 2007 requirements. All FY 2003 - 2007 budget estimates included in this book are notional only and subject to change.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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Table of Contents (Alphabetical)

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Defense Adv Research Projects Agcy
FY 2002 RDT&E PROGRAM

EXHIBIT R-1

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

Date: JUN 2001

Line No	Program Element Number	Item	Act	FY 2000 (Thousands of Dollars)	FY 2001 (Thousands of Dollars)	FY 2002 (Thousands of Dollars)	SEC
2	0601101E	Defense Research Sciences	1	62,940	108,806	121,003	U
		Basic Research		**62,940**	**108,806**	**121,003**	
9	0602110E	Next Generation Internet	2	35,425	14,862		U
14	0602301E	Computing Systems and Communications Technology	2	308,129	330,722	382,294	U
15	0602302E	Embedded Software and Pervasive Computing	2	30,000	52,407	75,561	U
16	0602383E	Biological Warfare Defense	2	124,272	166,769	140,080	U
18	0602702E	Tactical Technology	2	144,194	215,896	173,885	U
19	0602708E	Integrated Command and Control Technology	2	37,218	38,406		U
20	0602712E	Materials and Electronics Technology	2	239,526	261,883	358,254	U
		Applied Research		**918,764**	**1,080,945**	**1,130,074**	
35	0603285E	Advanced Aerospace Systems	3	19,187	37,474	153,700	U
44	0603739E	Advanced Electronics Technologies	3	245,187	219,467	177,264	U
47	0603760E	Command, Control and Communications Systems	3	175,665	128,778	117,451	U
48	0603762E	Sensor and Guidance Technology	3	176,843	139,858	203,095	U
49	0603763E	Marine Technology	3	21,845	27,937	41,497	U
50	0603764E	Land Warfare Technology	3	94,578	129,025	153,067	U
51	0603765E	Classified DARPA Programs	3	55,206	100,457	142,395	U
		Advanced Technology Development		**788,511**	**782,996**	**988,469**	
107	0605114E	BLACK LIGHT	6	4,961	4,954	5,000	U
118	0605502E	Small Business Innovative Research	6	42,831			U

Defense Adv Research Projects Agcy
FY 2002 RDT&E PROGRAM

EXHIBIT R-1

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

Date: JUN 2001

Line No	Program Element Number	Item	Act	FY 2000	FY 2001	FY 2002	SEC
				Thousands of Dollars			
126	0605898E	Management Headquarters (Research and Development)DARPA	6	32,163	32,379	36,937	U
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		RDT&E Management Support		79,955	37,333	41,937	
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		Total Defense Adv Research Projects Agcy		1,850,170	2,010,080	2,281,483	

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

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

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

(U) The Bio/Info/Micro Sciences project will explore and develop potential technological breakthroughs that exist at the intersection of biology, information technology and micro/physical sciences, and attempt to exploit these advances in the development of new technologies and systems of interest to the DoD. The project will apply information and physical sciences to discover properties of biological systems that cross multiple length scales of biological architecture and function, from the molecular and genetic level through cellular, tissue, organ, and whole organisms levels. Key focus areas include multidisciplinary programs in BioComputational Systems; Simulation of Bio-Molecular Microsystems; Bio Futures; Biological Adaptation, Assembly, and Manufacturing; and Nanostructure in Biology. Although this is a new project, the programs funded within it are not new starts. These efforts were initiated in FY 2001 and prior but were grouped together and separately funded to ensure the visibility of this important initiative.

(U) The Information Sciences project supports basic scientific study and experimentation in information sciences technology areas such as computational models, new mechanisms for performing computation and communication, innovative approaches to the composition of software, novel human computer interfaces, novel computing architectures, and automatic speech recognition research. This project will also explore

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

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

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

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

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

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

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

(U) Mission Description:

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

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

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

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

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

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

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

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

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

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

- Not Applicable.

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

- Not Applicable.

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

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

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

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

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

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

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

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

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

- Not Applicable.

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

- Not Applicable.

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

(U) Mission Description:

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

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

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

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

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

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

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

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

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

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

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

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

(U) **FY 2001 Plans:**

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

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

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

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

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

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

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

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

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

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

(U) <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 ES-01					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Electronic Sciences ES-01	13.696	21.371	19.743	19.370	20.547	23.347	23.847	23.847	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, and will contribute to the continued advancement of Next Generation Internet capabilities. Topics to be researched include emitters, detectors, modulators and switches operating from infrared to ultraviolet wavelengths, and related heterogeneous materials processing and device fabrication technologies for realizing compact, integrated optoelectronic modules.

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

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(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

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

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

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

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

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(U) **FY 2001 Plans:**

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

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

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

(U) **FY 2002 Plans:**

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

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

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- Characterize the impact of these new technologies on applications in the areas of bio-photonics, optically addressed memory and on-chip optical interconnects.
- Fabricate and test individual chip-level sub-assemblies for later use in prototype development.

- Semiconductor Technology Focus Center. ($ 6.055 Million)
  - Develop efficient platform-based design methodologies and low latency interconnect technologies for complex integrated circuits that have application in high performance signal processing and communications systems.
  - Develop methods for physics-based simulations of performance of deeply scaled switching device structures and circuit architectures.

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

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)									DATE June 2001	
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research					R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project MS-01					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Materials Sciences MS-01	31.282	52.658	20.957	22.778	24.053	19.053	19.053	19.053	Continuing	Continuing

(U) Mission Description:

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

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

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

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

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project MS-01

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

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

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

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

(U) **FY 2001 Plans:**

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

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

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project MS-01

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

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

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

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

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

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

(U) **FY 2002 Plans:**

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

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project MS-01

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

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

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

- Not Applicable.

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

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Next Generation Internet PE 0602110E , R-1 #9

COST *(In Millions)*	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	35.425	14.862	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Next Generation Internet NGI-01	35.425	14.862	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

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

(U) The Next Generation Internet (NGI) initiative has three goals: (1) promote experimentation with the next generation of networking technologies; (2) connect universities and national laboratories with high speed networks that are 100 - 1000 times faster than today's Internet; and (3) demonstrate revolutionary applications that meet important national goals and missions. The principal agencies involved in this initiative are DARPA, NSF, NIST, NIH and NASA. These agencies are sharing in funding this research and development effort. The DARPA activity will be aimed at part of the first two goals. DARPA will demonstrate end-to-end network connectivity at 1+ gigabits-per-second for 10 or more NGI sites. The network technologies to be addressed include multi-gigabit broadband networks, guaranteed quality of service mechanisms, and integrated network management. These technologies will be demonstrated in NGI developed testbed environments for defense-specific applications. Robustness of applications built atop diverse logical and physical infrastructure will be ensured with the development of new software and hardware tools that can automatically track and assess the inter-dependencies of physical layer resources. This project ends in fiscal year 2001.

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

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

- Gigabit-per-second Network Connectivity. ($ 17.000 Million)
  - Implemented variable rate access technologies and prototype of distributed optical switching capability compatible with 100 Gb/s optical network.
  - Implemented streamlined Internet over wavelength division multiplexed (WDM) protocol structure, eliminating two layers of existing telecommunications infrastructure.

- Network Management. ($ 18.425 Million)
  - Developed network planning and simulation technology to meet requirements for NGI scale networks.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Next Generation Internet PE 0602110E

- Demonstrated real-time (500-msec response) monitoring and control of network resources at all levels.
- Completed interconnection of Supernet testbed components and software with 2.5 gigabit-per-second access architecture, up to 10 gigabit-per-second backbone, and 100 Gb/s distributed switching capacity.
- Demonstrated information management and collaborative applications operating over NGI testbed.

(U) **FY 2001 Plans:**

- Network Architecture and Management for Robust Heterogeneous Gigabit Networks. ($ 6.795 Million)
  - Complete development architectural framework for ensuring maximum end-to-end system survivability.
  - Demonstrate prototype tool for assessing dependence of applications or networking performance on physical layer resources.
  - Specify robust heterogeneous network architecture that integrates gigabit wireless, wireline and satellite communications.

- Defense Applications of Gigabit Networks. ($ 8.067 Million)
  - Finish development of a virtual radar console tied to a physical radar and remotely accessible via wide-area network.
  - Demonstrate real-time, high-resolution imagery transfer over multiple streams of multi-gigabyte flows.
  - Enable streaming of raw (undigitized) sensor signal over wide-area links.

(U) **FY 2002 Plans:**

- Not Applicable.

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

	FY2000	FY 2001	FY 2002
Previous President's Budget	36.473	15.000	0.000
Current Budget	35.425	14.862	0.000

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(U) Change Summary Explanation:

FY 2000	Decrease reflects minor repricing and SBIR reprogramming.
FY 2001	Decrease reflects the Section 8086 reduction, the government-wide rescisson and minor repricing.

(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 Computing Systems and Communications Technology PE 0602301E, R-1 #14					
COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	308.129	330.722	382.294	332.374	326.200	338.300	353.300	368.300	Continuing	Continuing
JASON ST-01	1.190	1.512	1.500	1.500	1.500	1.500	1.500	1.500	Continuing	Continuing
Intelligent Systems and Software ST-11	71.454	74.900	87.303	61.536	58.362	58.057	68.057	68.057	Continuing	Continuing
High Performance and Global Scale Systems ST-19	158.266	125.346	157.666	132.838	152.338	169.743	169.743	179.743	Continuing	Continuing
Software Engineering Technology ST-22	16.630	17.839	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Information Assurance and Survivability ST-24	60.589	84.241	77.738	85.800	64.500	64.000	64.000	64.000	Continuing	Continuing
Asymmetric Threat ST-28	0.000	26.884	58.087	50.700	49.500	45.000	50.000	55.000	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 provide analysis of critical national security issues.

(U) The Intelligent Systems and Software project develops new information processing technology concepts that will lead to fundamentally new software and intelligent systems capabilities. This will enable advanced information systems to more effectively accomplish decision-making tasks in stressful, time sensitive situations and create efficient software-intensive defense systems.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E

(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 Software Engineering Technology project funds the core efforts of the Software Engineering Institute (SEI). Beginning in FY 2002, the funding for the SEI program has transferred from DARPA to OSD PE 0603781D8Z.

(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 under attack, and will lead to generations of stronger protection, higher performance, and more cost-effective security 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 suite of tools to better detect and prevent attacks upon our critical DoD infrastructures.

(U) Program Change Summary: (*In Millions*)	**FY2000**	**FY 2001**	**FY 2002**
Previous President's Budget	320.648	376.592	347.779
Current Budget	308.129	330.722	382.294

(U) Change Summary Explanation:

FY 2000 Decrease reflects SBIR reprogramming and minor program repricing.

FY 2001 Decrease reflects the net effect of specific and general congressional program reductions; congressionally added funds for the Reuse Technology Adoption Program; the Section 8086 reduction; and the government-wide rescission.

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FY 2002 Increase reflects the net effect of expansion for new initiatives in network embedded software technologies and high performance computing architectures and rephasing of FY 2002 programs following the FY 2001 congressional program reductions, offset by the transfer of the Software Engineering Technology funding (Project ST-22) to OSD.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E, Project ST-01					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
JASON ST-01	1.190	1.512	1.500	1.500	1.500	1.500	1.500	1.500	Continuing	Continuing

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

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

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

- JASON. ($ 1.190 Million)
  - Continued studies of interest to DoD in multiple disciplines such as: counter proliferation of chemical and biological weapons; space based radar; small payload space launch systems; advanced computing; multi-layered infrastructure defense; advanced sensor technologies including increased radar noise floor and deep buried target characterization; dispersed land forces technology; battlefield information systems and military communications; ultra low power electronics; fiber lasers; and self-monitoring materials.

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

- JASON. ($ 1.512 Million)
  - Continue 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.

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

(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 Computing Systems and Communications Technology PE 0602301E, Project ST-11					
COST *(In Millions)*	FY 2000	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	71.454	74.900	87.303	61.536	58.362	58.057	68.057	68.057	Continuing	Continuing

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

(U) This project develops new information processing technology concepts that will lead to fundamentally new software and intelligent systems capabilities. This will enable advanced information systems to more effectively accomplish decision-making tasks in stressful, time sensitive situations and create efficient software-intensive defense systems.

(U) A major consideration in military missions is the ability to exploit large quantities of heterogeneous data gathered from a multiplicity of sources, languages and modalities (text, speech, video, etc.). Key technical challenges lie in being able to (a) develop "dialog interaction" for warfighters to talk with computers, and through these computers, to command centers in a hands-free fashion to allow the warfighter to use their hands for more critical warfighting efforts; (b) retrieve, summarize and extract information from multiple foreign language streams through the development of machine translation and automatic construction of information products; and (c) access, organize and disseminate information contained in large, dynamic, multi-media document streams. This involves developing repository techniques for rigorously registering and classifying multimedia document streams, integrating knowledge, and effectively employing statistically based techniques for extracting critical content from large volumes of data.

(U) The Situation Analysis component is comprised of the Information Management (IM) program which will develop persistent identification, registration, and tracking of digital objects, to create an information representation which incorporates unique naming, descriptive hierarchical or granular organization of multi-media data streams. The IM program will develop algorithms and tools for clustering, classifying, visualizing, navigating and extracting critical data from extreme high volume sources. The greatest challenge in this project is the development of algorithms that can keep up with the rapid change of information and arrival of multiple data streams in high volume during a crisis. DARPA's IM program will provide the Defense analyst with the capability for high performance retrieval, search and extraction of data by developing repository technology as well as analysis environments in an interoperable framework. The technology developed by IM is being evaluated on testbeds for the Unified Commands.

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(U) The Situation Presentation and Interaction component is comprised of DARPA's Communicator program. Warfighters in the field are called upon to respond rapidly to a wide range of unpredictable situations that require collective actions across services and components. DARPA's Communicator program will develop the intuitive, hands-free, mobile, networked access to information and the ability to create new information for others using spoken language. The Communicator program will provide the warfighter with wireless, mobile, networked communication devices to communicate with command centers, logistics services and support forces on the battlefield without touching a keyboard. Dialog interaction software distributed in a network of smart devices will use a new "dialog management and context tracking" capability to facilitate interactions among human users as well as suites of computer applications. Key technical problems to be overcome include: (a) the analysis of spoken information in the context of a particular problem; (b) natural generation of information in context; and (c) anytime, anywhere intuitive access to information.

(U) The Intelligent Software for Multi-Lingual and Coalition Environments component is comprised of the Translingual Information Detection, Extraction and Summarization (TIDES) program. The TIDES program will develop machine translation ability for a set of foreign languages, at State Department Level 3 (defined as the level at which fluent communication is possible). Key new techniques for machine translation are statistically based corpus analysis tools, which enable the automatic extraction of grammar and vocabulary of foreign languages. It is expected to reduce the time required for developing level 3 knowledge by a factor of 10-15. The TIDES program will also acquire and utilize knowledge through a multi-stage process of query formulation, information retrieval, document translation, topic identification, information extraction and content summarization. The key insights into the methods pioneered in TIDES come from the realization that these goals are not sequential and independent but are interrelated. This inter-dependence can be exploited by information lattices which provide both feedback and feedforward into what used to be serial processes. The TIDES goals are to achieve 85 percent accuracy in topic identification; 80 percent accuracy in people, places and event identification; and 70 percent accuracy in establishing relationships among identified entities.

(U) The Composable High Assurance Trusted Systems (CHATS) program is developing the tools and technology that enable the core network services to protect themselves 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 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.

(U) The DARPA Agent Markup Language (DAML) program will develop military software tools for use on InteLink and the emerging C2Link system. The program's focus is to develop technologies to enhance interoperability; that extend the reach of the World Wide Web to include program, sensors, and other data sources, and to enable agent-based programs to use these information sources. DAML will develop a

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software language that ties the information about a web resource to machine-readable semantics (ontology), including ontologies for InteLink briefings and military operations. This effort will provide new technologies for the intelligent integration of information across a wide variety of heterogeneous military sources and systems in real time.

(U) 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 developed technologies will be evaluated in challenge problem experiments in the domain of microbiology and bioinformatics. Technology challenges to be addressed include direct knowledge entry by non-AI experts, coordinating entry of possibly overlapping and inconsistent knowledge by multiple geographically distributed individuals, and achieving a knowledge entry rate without AI training of twice that of today's AI expert which also results in an enormous and comprehensive knowledge base (10^6 axioms).

(U) Under the Taskable Agent Software Kit (TASK) program, software agent creation tools will be developed that reduce the per-agent development/customization cost for advanced military systems. Software agents are a next generation of software that will be able to automatically accept abstract tasking, get needed information, decide how to solve simple problems, help the user solve difficult problems, route useful information and otherwise take action on the user's behalf. This effort will explore mathematical techniques in the areas of Control Theory, Decision Theory, and Operations Research for correctly modeling and analyzing agent environments and the behaviors of agents in these environments. Experiments will reveal the qualitative aspects of environments that favor the use of agent-based systems over object-based systems. Models derived from this program will allow the development of rigorous qualitative and quantitative comparisons of agent behaviors with respect to domain and problem features.

(U) The Human Identification at a Distance (HumanID) program objective is to develop automated multi-modal, multi-biometric surveillance technology for identifying humans at a distance as an enabler for force protection and early warning against Asymmetric Threats. HumanID redefines and renames the program formerly known as Image Understanding for Force Protection (IUFP) to more fully represent the technologies being explored under this program. HumanID seeks to improve individual biometric technologies with multiple sensor signatures for multi-range, round-the-clock processing. The goal of this project is to positively identify humans at a distance, at any time day or night, during all weather conditions, with non-cooperative subjects, possibly disguised and alone or in groups. This program is funded in the Asymmetric Threat project (ST-28) beginning in FY 2001.

(U) The High Confidence Computing Architectures project will realize the promise and potential of nano-computational devices and materials for building computational architectures with high functionality for perennially computationally hungry and multi-mission adaptive DoD applications. Future high capacity/high confidence computing systems face some basic issues: (1) extensibility of Moore's Law; (2) availability/

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reliability of large scale computing systems; (3) integral architectural security; and (4) economic viability of narrowly focused computing solutions. The techniques for architecting, constructing, and programming computational systems from nano-devices require the development of novel methods quite different from current methods, relying on precise interconnections of reliable parts. Architecture and functionality are best designed based on local interaction and self-assembly of devices, in 2-D or 3-D. The programming and use of such a system will be based on time-varying and irregular interconnections of devices. This program will develop breakthrough-enabling technologies for the construction and use of systems incorporating vast numbers of nano-devices that can be manufactured and deployed without precise control of placement or interconnect and without individual testing.

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

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

- Situation Analysis. ($ 25.825 Million)
  - Demonstrated statistically based semantic analysis capabilities.
  - Developed persistent queries for audio and video streams to detect user-defined significant events and to generate alerts.
  - Demonstrated distributed prototype of information-value-based retrieval.
  - Demonstrated scalable implementation of public and secure versions of Digital Information Pheromones (DIP) characterization of network resources.
  - Developed component theory building technologies enabling direct knowledge entry by artificial intelligence novices.
  - Demonstrated language and diagram interface, analogic reasoners, and theory explanation capabilities, as well as, developed 10-20 core theories (5K-10K axioms each).
  - Developed mathematical techniques for modeling and analyzing agent behaviors.

- Situation Presentation and Interaction. ($ 25.284 Million)
  - Specified network-based service architecture Application Program Interface’s (API’s) for key components of dialogue architecture.
  - Demonstrated usability of dialogue interaction with confirming sub-dialogue to reduce task completion time by 80%, using metrics-based evaluation.
  - Evaluated dialog for small unit logistics demonstrated in the Listen, Communicate, Show (LCS) Marine project.
  - Expanded dialog evaluation beyond the travel scenario with method for cross task comparison.

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- Expanded dialog interaction into vehicles with initial investigation of feasibility within acoustic environment of automobiles.
- Expanded dialog interaction with information services for more natural automatically generated dialogue and speech.
- Developed preliminary ontology for InteLink briefings and released initial language design specifications.

• Intelligent Software for Multi-lingual and Coalition Environments. ($ 12.122 Million)
- Developed a translingual C4I database for use in U.S. and Republic of Korea coalition operations.
- Demonstrated with operational users an automated translation of briefing documents, cross language information retrieval (Korean and English), and speech-to-speech translation (English-Korean).
- Expanded investigation into capability of providing machine translation capabilities for new language pairs with smaller sized training corpora.
- Implemented TIDES open system architecture version 0.1 providing a web-based environment to support plug-in component experiments.
- Conducted experiments involving humanitarian assistance/disaster relief/consequence management in cooperation with Third Fleet.

• Intelligent Sensor Processing (Human Identification at a Distance). ($ 6.223 Million)
- Initiated theoretical studies of candidate biometric features, analysis of biometric technologies, Concepts of Operations and scenario development for human identification from a distance.
- Began generation of a database containing known biometric feature data for metric-based evaluation of candidate techniques.

• Reuse Technology Adoption Program (RTAP). ($ 2.000 Million)
- Identified technologies for definition and specification of agile components.
- Developed business model to explore ways to reduce the time to get advanced DARPA technologies into the hands of the military services.

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

• Situation Analysis. ($ 17.822 Million)

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- Deploy scalable prototype analysis environment in defense application with cross-repository information analysis functionality (semantic retrieval, indexing, value filtering, user defined alerting, and categorizing).
- Demonstrate secure distributed repository architecture supporting digital objects of arbitrary type.
- Develop and conduct value-added evaluation.
- Demonstrate direct knowledge entry by a novice (2K axioms/month) for a military problem.

• Situation Presentation and Interaction. ($ 15.592 Million)
  - Demonstrate and evaluate dialogue performance for Project Marine; complete a complex travel task requiring negotiation twice as fast with automated service support as with the best human assistance.
  - Demonstrate and evaluate interaction of tasks with real-time, web-based, public data.
  - Demonstrate in-vehicle dialogue for information services and navigation.
  - Identify short, intermediate, and long-term core Automatic Speech Recognition (ASR) research objectives - emphasizing high risk, high yield algorithm development.

• Intelligent Software for Multi-lingual and Coalition Environments. ($ 20.256 Million)
  - Extract, translate, and correlate named entities from unstructured documents in multiple languages.
  - Demonstrate initial summarization in English of foreign language documents using frame semantics.
  - Release initial version of comprehensive, cross-language processing architecture for eventual standardization.
  - Experiment in multilingual, intelligence analysis, demonstrating benefits of cross-language information extraction, detection, and summarization capabilities.
  - Demonstrate initial toolkits for rapid development of cross-language capability in minority or other new languages.

• DARPA Agent Markup Language (DAML). ($ 13.135 Million)
  - Complete DAML language specifications.
  - Release working version of Briefing Tool for Intelink.
  - Release working version of DAML Search Tool on Intelink.
  - Release working version of DAML Ontology Creation Tool on Intelink.
  - Define requirements to DAML for supporting non-pre-planned Agent interoperations.

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- Demonstrate utility of DAML Ontology Creation Tools to enhance the storage, access and organization of archival information at the Center for Army Lessons Learned.
- Develop first order rules for data extraction and update rates for web information cached remotely.
- Investigate alternative approaches to composable high assurance trusted systems based on the Robust Open Source development model.
- Investigate the feasibility of and alternative approaches to high assurance trusted implementation languages and tools.
- Investigate 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). ($ 5.315 Million)
  - Define metrics for analysis of agents in the C4I military environment.
  - Perform agent-design method experiments.

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

(U) FY 2002 Plans:

- Situation Presentation and Interaction. ($ 8.904 Million)
  - 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 Quantico Marine Base.
  - Define and publish final (release) version of the Galaxy-II+ 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.

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- Evaluate a follow-on research program for dialog systems.

• Intelligent Software for Multi-Lingual and Coalition Environments. ($ 25.286 Million)
- Demonstrate methods for Machine Translation development in languages for which annotated corpora and dictionaries do not yet exist.
- Demonstrate methods for minority language translation in a South American language related to drug intervention.
- Develop Level-1 capability for a new language (rudimentary knowledge of the foreign language and an ability to effectively use a bilingual dictionary) in 1 month.
- Explore methods for comparable as well as parallel corpora (text in two languages about the same topics, but not sentence by sentence translations of each other) in statistical machine translation and apply them in Chinese.
- Demonstrate new story detection capability and baseline performance measures for future efforts.
- Demonstrate bioprecursor feature extraction application using broadcast and public news about public health and related issues.
- Demonstrate "delta" information provision (providing only what's different from before) in a portal for broadcast news.
- Retrieve information from European language documents with English queries 75% as well as English Information Retrieval.
- Demonstrate 15% improvement in monolingual information retrieval using an information web infrastructure of entities, events, and threads.
- Demonstrate cross document, cross language summarization in multiple languages.
- Experiment in automatic biography or narrative generation using time-ordering summarization techniques.
- Demonstrate integration of topic detection, named entity extraction, and summarization in a web portal across news sources in multiple languages.
- Demonstrate effective access to on-line Arabic audio and text sources.
- Develop TIDES Architecture 1.0 for plug-and-play compatibility among research components for specified end-to-end multilingual applications.
- Perform Strong Angel operational prototype evaluation for RimPac '02 using real intelligence operators.

• Composable High Assurance Trusted Systems (CHATS). ($ 7.400 Million)
- Develop an operational prototype of the Composable High Assurance Trusted System.
- Develop operational capability of candidate high assurance trusted implementation language and tools.

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- 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). ($ 15.882 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.
  - Develop technology for dynamic prioritization management.
  - Develop technology for intelligent information delivery under changing bandwidth conditions.

• Rapid Knowledge Formation. ($ 12.960 Million)
  - Demonstrate knowledge entry rate of 50K axioms/month from each of 25 subject matter experts in a biowarfare challenge problem.
  - Assess multi-user (40-50 individual) system design.
  - Resolve scaling bottlenecks.
  - Create complex theories using undergraduate biology and medical curricula.

• Taskable Agent Software Kit (TASK). ($ 6.871 Million)
  - Publish correct mathematical techniques for modeling and analyzing agent behaviors.
  - Perform empirical validation experiments.

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- High Confidence Computing Architectures. ($ 10.000 Million)
  - Investigate basic composition technologies, such as computing materials, computational devices, memory systems, communication fabrics, storage devices and software.
  - Identify potential application problem set and technical, economic and market requirements.

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

- Not Applicable.

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

- Not Applicable.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
High Performance and Global Scale Systems ST-19	158.266	125.346	157.666	132.838	152.338	169.743	169.743	179.743	Continuing	Continuing

(U) Mission Description:

(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 the following components:

(U) The Global Mobile Information Systems effort enabled mobile wireless users to automatically form ad hoc networks and to exchange a wide range of information both within the ad hoc network and between wireless and fixed networks. This program developed technologies to: ensure the robust and secure operation of the network, dynamically adapt bandwidth to Radio Frequency (RF) environment, and dynamically reconfigure the network to counter jamming and to provide highest quality-of-service. The program developed and integrated technologies and techniques at the networking, wireless link/node, and applications levels, enabling access to and utilization of the full range of services available in the Defense Information Infrastructure. This program ended in FY 2000.

(U) The Networking component develops active networking technologies and associated network management capabilities to support a new paradigm of Internet Protocol (IP) routing and transmission and deeply networked systems. Research is coordinated with DoD, NASA, DoE, NSF and other federal agencies.

(U) The Data Intensive Systems and Software component develops software and hardware technologies for data-starved applications. This component will develop a new approach to computer memory organization that will eliminate severe bottlenecks in present designs.

(U) The Adaptive Computing Systems (ACS) program develops new approaches to the design of computer hardware that incorporates dynamic configuration capabilities. The resultant devices will allow 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. In addition, the ACS project is developing software and component level technologies for use in embedded systems that leverage novel signal processing technologies. The Mission Specific Processing

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(MSP) program 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. The technology developed by the Mission Specific Processing (MSP) program will facilitate high performance processing in future space-based and/or miniature systems that require extremely high processing throughput while consuming the minimum possible volume, weight and power. Because of its applications focus, funding of MSP will continue in FY 2002 from PE 0602702E, Tactical Technology, Project TT-06, Advanced Tactical Technology.

(U) The Ultra High-Performance Networking Applications component will develop robust, survivable inter-networking architecture that will minimize vulnerability posed by the growing complexity and brittleness that is seen across physical layer networking architectures today. In the Real-time Gigabit Flow Applications component of this project, new gigabit per second communication capabilities over alternate physical media will be demonstrated such that gigabyte flow transfers can be demonstrated to sites lacking in fiber infrastructure and connectivity. Multi-channel techniques in temporal, spatial, and spectral domains will be invoked to enable the new capabilities.

(U) The Systems Environments component develops scalable software, which is tailored toward easing the use of systems by application programmers. This includes run-time services, resource allocation, and experimental applications. Additionally, it will develop technology to support faster, more reliable development of software for distributed embedded software for intelligent systems. This technology will enable programmers to safely introduce cross-cutting aspects such as synchronization, fault tolerance, and memory hierarchy management into basic programs that implement intelligent software interaction with a diverse suite of sensors and actuators in real-time.

(U) The Signal Processing and Power Aware Computing component is developing: 1) software and component level technologies for use in embedded systems that leverage novel signal processing technologies; and 2) innovative power management strategies, at system through chip level.

(U) A follow-on to the Defense Technology Integration effort budgeted in previous years, the Mobile Code Software program 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.

(U) Future defense uses of the network will have an increased emphasis on the direct exchange of real-time sensor-derived information among autonomous embedded devices. This reflects a significant change in network traffic from the present environment, which is dominated by the

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exchange of symbolic information among human users. The architectures and protocols needed to effect this transition will be investigated in the Networked Embedded and Autonomous Software component of this project. The autonomous software component will develop embedded software technologies for programming autonomous mobile robots to perform a variety of military tasks. The task of explicitly programming mobile robots to operate independently in complex, dynamic environments, such as those relevant for military applications, has thus far proven intractable. Conventional, direct programming strategies attempt to micro manage all top-level goals and constraints from the bottom up. That approach has proven unacceptably brittle, since it requires accurate knowledge of every possible contingency, a priori. This program is pursuing several alternative approaches to synthesizing innate (pre-programmed) competencies with learning-derived competencies for perception and control similar to the way biological systems work. The long-term goal is to enable future programming of autonomous mobile robots for real world, military missions as easily as we program assembly line robots in the auto industry.

(U) The goal of the Systems Engineering for Miniature Devices (SEMD) program is to utilize a systems methodology for integrating miniature device technology that traditionally occurs in a disparate fashion. This research project includes 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) Information Technology Expeditions will develop technologies for software programmable adaptive computing systems. These are devices whose hardware is exposed to software for changing their functionality, algorithms, and power/energy consumption. Such devices are important for deeply networked components such as mobile computing elements whose functionality needs to be changed depending on the applications, level of battery power and speed of response.

(U) The Mixed Initiative Control of Automa-teams (MICA) program will develop the theory, algorithms, software, modeling and simulation technologies 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. The MICA program will provide a commander the operational and mission planning tools to select optimal team composition, tasking and sub-tasking appropriate for mixed initiative control of automatons in a military operational environment.

(U) The Augmented Cognition program focuses on software power tools to augment the warfighter's cognitive capabilities. This is a new area for expanding human capabilities using information technology that is similar to the augmentation of the human through devices like weapons, vehicles, and sensors. The hypothesis is that impressive progress in neural science, computation, and miniaturization can now be leveraged to enable

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new concepts of warfare. Success will provide significant advantage to our warfighters. Exploratory efforts in augmented cognition have demonstrated that there are order of magnitude improvements to be gained through improving the spatial, temporal and sensory inputs to human operators. The Augmented Cognition effort will develop methods to integrate digital support for memory, perception, and thinking and then link that support with context state information to directly improve the cognitive performance of the warfighter.

(U) The High Productivity Computing Architecture program creates a new generation of high productivity computing systems characterized by balanced system architecture including high effective bandwidth, robust implementation, and responsive software/hardware components. These new systems will address the inherent difficulties associated with the development and use of current high end systems and applications such as programming productivity, performance portability, scalability, reliability, and tamper resistance. This program is targeting the high end computing medium to long term national security application requirements where U.S. superiority is threatened.

(U) The Robust High Assurance Systems program will extend recent advances in quality-of-service (QoS) assurance technologies (such as bandwidth and processor reservation, feedback control, and dynamic adaptation) to accommodate other mission critical properties, including dependability and security, providing a technology base for the development of high confidence distributed embedded systems. Activities include: (1) development of a framework that allows security and dependability attributes to be explicitly considered as QoS properties and that further allows application security and dependability requirements to be balanced against its performance needs; (2) development of robust high assurance QoS mechanisms and managers that are resistant to compromise; (3) incorporation of trust and reliability models into resource management decisions; (4) integration of security modeling and failure detection with performance monitoring as triggers for adaptive resource management; (5) development of robust, stable adaptation algorithms that are resistant to exploitation; and (6) development of policy tools for controlling these mechanisms.

(U) The Mobile Wireless Networking program will develop the technology required to significantly enhance the survivability of mobile and wireless tactical networks. These technologies will ensure future combat networks will continue operation during attack, defeat attempts to disrupt and exploit tactical battlefield communications, and recover from damaging attacks while maintaining the security of network traffic. Additionally, these technologies will enable the secure and rapid creation of mobile and wireless communications networks within hostile environments for military operations.

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(U) **Program Accomplishments and Plans:**

(U) **FY 2000 Accomplishments:**

- Global Mobile Information Systems. ($ 13.107 Million)
  - Developed prototype of high data-rate untethered nodes incorporating adaptive link controls and frequency agile RF front end with capability to adapt to available spectrum frequencies.
  - Demonstrated self-organizing, self-healing mobile wireless networks supporting Quality of Service (QoS) routing utilizing Internet and Asynchronous Transfer Mode (ATM) networks.
  - Demonstrated network security techniques, including over the air re-keying, in mobile wireless multihop network.
  - Integrated GloMo simulation models and conducted scenario simulations for mobile wireless networks (100 to 10,000 nodes).

- Networking. ($ 36.832 Million)
  - Demonstrated use of active network approach to achieve live protocol updates within two roundtrip times.
  - Provided initial release of prototype active network toolkits for end-user stations and network elements including performance measurement capabilities.
  - Provided engineering analysis of active network performance.
  - Initiated development of new models of traffic and network applicable to varying scales of time and network sizes, which are suitable for predicting network behavior.
  - Initiated building a network measurement methodology to support near real-time prediction using modeling and simulation tools.
  - Designed and demonstrated prototype software for a digital amphitheater using gigabit interconnectivity.

- Data Intensive Systems and Software. ($ 20.656 Million)
  - Designed processor in memory very large scale integration (VLSI) components that support in situ processing of application data.
  - Implemented compiler that generates code compatible with processor in memory architecture.
  - Simulated data-intensive systems, demonstrated 10-fold performance improvement on critical DoD applications.

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- Adaptive Computing Systems (ACS). ($ 24.782 Million)
  - Implemented initial Adaptive Computing Systems (ACS) analysis and development tools.
  - Developed high-level design entry tools/development environments for ACS, e.g., for Java, C, MatLab, Khoros.
  - Completed fabrication of single clock cycle context-switchable reconfigurable computing device.
  - Implemented ACS reference platforms and supporting development environment.
  - Demonstrated ACS self-test, diagnosis and reconfiguration for fault tolerance.
  - Published updated ACS benchmarks.

- Systems Environments. ($ 23.100 Million)
  - Released reference implementation of mission-critical Quality of Service (QoS) architecture.
  - Released prototype operating system with partitioned resource management for strict QoS guarantees.
  - Provided a joint demonstration of QoS management software with Aegis advanced computing testbed; demonstrated interoperability of combat and Command, Control, Communications Intelligence Surveillance Reconnaissance (C4ISR) functions through over-the-horizon track correlation and engagement deconfliction; demonstrated scalable resource management to handle Theater Ballistic Missile (TBM) debris fields incorporating initial trend analysis capability to predict and prevent deadline violations.

- Signal Processing and Power Aware Computing. ($ 19.201 Million)
  - Implemented prototype multiprocessor event collection and analysis system and automated stress test generator for signal processing applications; demonstrated use of high performance signal processing for weapon systems applications.
  - Initiated Power Aware Computing and Communication (PAC/C) individual power aware technology research efforts.
  - Initiated early exploration of power aware tool frameworks, databases and metrics.
  - Explored potential operational environmental effects on low power electronics.
  - Developed novel architectures for reprogramming field programmable gate arrays using adaptive software.

- Defense Technology Integration. ($ 12.636 Million)
  - Mobile Code Software.
    - - - Analyzed ability of autonomous software to predict, negotiate and track resource requirements under changing environment and time constraints.

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- - Developed strategy for the rapid assessment of computation cost of complex sets of constraints.
- - Implemented software toolkit for knowbot development, generation and deployment.
- - Created experimental platform for negotiation-based real-time resource management.
- - Measured the real-time base line for different negotiation protocols using the experimental platform.

– Information Technology Expeditions.
- - Developed architectures for secure collaboration over an unreliable and dynamic network.
- - Developed power and energy aware operating systems for mobile computing elements.

• Next Generation High End Computers Required for National Security. ($ 3.091 Million)
– Developed massively parallel processor (MPP) computers that minimized porting effort from current vector platforms.
– Demonstrated use of MPP architecture for interactive National Security applications.

• Systems Engineering for Miniature Devices. ($ 4.861 Million)
– Established the infrastructure to carry out integrated micro-miniature device research.
– Developed a collaborative environment for the integrated, concurrent design of all aspects of a micro-miniature platform.

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

• Networking. ($ 24.045 Million)
– Investigate alternative approaches to large-scale network engineering including simulation technology.
– Demonstrate performance improvements of 100 percent for large multicast sessions based on active suppression of redundant acknowledgement and retransmission messages.
– Integrate active network capabilities into Run-Time Infrastructure (RTI) for use with high-level architecture (HLA)-compliant simulations; prepare for joint demonstration with Defense Modeling and Simulation Office (DMSO).
– Develop models of network control suitable for on-line parameter tuning, dynamic reconfiguration, fault detection, and for meeting DoD mission critical requirements.
– Validate modeling and simulation tools, and demonstrate predictive power of the models using measured network data.

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- Implement and demonstrate application non-specific congestion manager that coordinates and ensures fair throughput for multiple applications.
- Test radar image enhancement using coherent processing of signals from multiple radar sources connected by a very high-speed network.
- Develop survivable key management and distribution architectures to protect against compromise and enable rapid network recovery and reconstitution.

- Data Intensive Systems and Software. ($ 11.699 Million)
  - Prototype demonstration of processor in memory (PIM) array.
  - Demonstrate advanced cache-based approaches for data-intensive applications.

- Adaptive Computing Systems (ACS). ($ 18.981 Million)
  - Implement final Adaptive Computing Systems (ACS) design tool suites using high-level entry, e.g., for Java, C, Matlab, and Khoros.
  - Demonstrate 100x – 1000x reduction in compilation time for ACS implementations.
  - Implement C compiler for hybrid chips.
  - Implement ACS/heterogeneous processing Matlab design environment.
  - Implement selected benchmark algorithms using ACS automated development environmental/tool aided design.
  - Demonstrate ACS defense system insertion for high dimensionality sonar beamforming, synthetic aperture radar (SAR), signal processing, and automatic target recognition (ATR).
  - Extend ACS development tools to support application specific integrated circuit (ASIC) development for highly constrained signal processing applications.
  - Define requirements for tool enhancements needed to implement ASICs.
  - Begin design of platform independent development tools.
  - Define 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.
  - Begin the design of custom cell libraries and module generators.
  - Begin simulation and verification of custom design techniques.
  - Complete wideband adaptive radar system architecture study.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E, Project ST-19	

- Systems Environments. ($ 26.243 Million)
  - Release prototype distributed object software with real-time Quality of Service (QoS) management.
  - Demonstrate support for mixed workloads of hard, soft, and non-real-time applications.
  - Demonstrate QoS-driven fault detection and recovery within 500 milliseconds.
  - Develop intermediate representations and mechanisms for code composition and transformation.
  - Develop models, specifications, code interpretations, and implementation mechanisms for embedded systems aspects, such as timing and fault tolerance.
  - Develop common graph-based program representations for software analysis.
  - Develop initial reusable embedded system aspect software.
  - Perform initial assessment of using security monitoring to trigger adaptation (detection latency, effectiveness of response, stability).

- Signal Processing and Power Aware Computing. ($ 20.455 Million)
  - Demonstrate flight-capable Synthetic Aperture Radar (SAR)/Automatic Target Recognition (ATR) system recognizing 30 target types in presence of camouflage concealment deception.
  - Prototype demonstrations of power aware technologies.
  - Identify potential small and medium scale power aware prototype candidates.
  - Define plug-in-component parameters and metrics.
  - Initiate primary power aware framework tool suite efforts and Application Program Integration (API) standardization efforts.

- Mobile Code Software. ($ 17.782 Million)
  - Demonstrate and evaluate software agent's ability to approximate behavior tradeoffs and to utilize negotiation in advanced logistics scenario with a 3-second response requirement.
  - Demonstrate and evaluate software agent's ability for bottom-up organization in advanced logistics scenario with 100-1,000 components.
  - Prototype implementation of negotiation technology in real-time scenario with a 500-millisecond response requirement.
  - Develop methods for maintaining and updating critical information (system and resource states, global time, etc.) system-wide, without centralized depository.
  - Investigate event/time triggered system synthesis methods subject to time, functional, performance, safety and security constraints.

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- Investigate design methods of embedded generators that guarantee selected behaviors of the generated systems.

- Information Technology Expeditions. ($ 2.691 Million)
  - Demonstrate adaptive reprogramming of hardware within a single clock cycle.
  - Define 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)
  - Continue developing massively parallel processor (MPP) computers that minimize porting effort from current vector platforms.
  - Continue demonstrating use of MPP architecture for interactive National Security applications.

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

- Active Management and Control of Networks. ($ 18.797 Million)
  - 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.
  - 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.
  - Develop reduced order and aggregate models of network suitable for faster prediction and control; and characterize accuracy.

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- Develop the ability to predict internal and end-to-end behavior of large networks at multiple time scales and resolutions.
- Implement models and control strategies in a wide area experimental 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 Applications. ($ 24.731 Million)
- Ultra High-Performance Access.
  - - Prototype 40 Gbps interface card for network and sensor I/O.
  - - Design secure communication interfaces for gigabit-end flows.
  - - Demonstrate scaling of port controller speeds by an order of magnitude.
  - - Develop and demonstrate optical access nodes based on fast tunable-channel transmitters.
  - - Demonstrate gigabit wireless router that uses adaptive protocols.
  - - Prototype quality of service-based resource management algorithms for adaptive gigabit wireless routers.
  - - Prototype advanced protocol for routing finest grained flows.
  - - Design metadata for service components, sensors and devices, together with service registration mechanism.
  - - Demonstrate search engines for distributed services and devices. - - Simulate a lightweight protocol (non-GPS-based) for high-accuracy geo-localization.
  - - Design wireless multi-hop algorithms for establishing network connectivity within a window of a few seconds.

- Real-Time Gigabit Flow Applications.
  - - 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.
  - - Construct a portable node with multi-gigabit wireless interfaces.
  - - 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.

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- - Demonstrate multiple video blanket media streams and client side browsers for display of these streams.

- Systems Environments. ($ 17.000 Million)
  - Develop techniques for incremental (partial, completion) software analysis.
  - Develop techniques for incremental formal transformation.
  - Develop deterministic and probabilistic timing services for time-based aspects.
  - Develop Quality-of-Service (QoS) aware data persistence services.
  - Demonstrate pair-wise interacting aspects and transformation strategies.

- Power Aware Computing. ($ 16.360 Million)
  - 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.

- Mobile Code Software. ($ 13.850 Million)
  - Demonstrate ability to identify and characterize autonomous negotiation targets needed for negotiated cooperation.
  - Demonstrate ability for hierarchical coalition formation.
  - Demonstrate negotiation protocols for large, hierarchically organized coalitions.
  - Integrate utility for the selection of negotiation strategies.
  - Demonstrate stable goal tracking ability under changing environment.
  - Demonstrate avoidance of conflict by changing plans.
  - Prototype implementation and evaluation of negotiation in real-time mission planning.
  - Prototype implementation of adaptive scans scheduling using negotiation protocols.
  - Demonstrate ability to negotiate tasks in electronic countermeasures and common challenge problems in less than 20 minutes.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E, Project ST-19

- Networked Embedded and Autonomous Software. ($ 30.000 Million)
  - Conduct experimental and theoretical investigations on phase-transition effects in constraint satisfiablity problems.
  - Investigate methods for the prediction of characteristics and for the detection of proximity of phase transitions.
  - Develop experimental prototypes for transition-aware constraint solvers.
  - Develop scalable, lightweight, fault tolerant coordination-services (time, consensus, synchronization and replication) for network embedded software technology applications.
  - Investigate deterministic and probabilistic methods for self-stabilizing protocols.
  - Investigate design approaches for the customization of coordination-services.
  - 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.
  - 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.
  - Demonstrate adaptive generation of complex behaviors.
  - Demonstrate multi-sensor based, autonomous navigation.
  - Demonstrate scalable behavior autonomous control laws.
  - Demonstrate robust planning using Markov decision models for plan adaptation.

- Mixed Initiative Control of Automa-teams (MICA). ($ 12.000 Million)
  - Develop technologies, algorithms and software tools for ordering task execution and optimizing team member collaboration.
  - Cultivate collective trajectory generation technology for teamed entities with collision avoidance and threat avoidance or engagement.
  - Develop technologies, algorithms and software tools delivering recommended courses of actions to a commander or operator with appropriate feedback information.

- Augmented Cognition. ($ 8.128 Million)
  - Conduct initial demonstration and evaluation to show that an over-abundance of sensor information can be transformed into actionable information using augmented components of memory, perception and thinking.

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- Develop spatial and temporal coding techniques to augment human memory and information aesthetics to significantly improve cognitive utility.
- Perform evaluations of methods to combine human and digital memory that extend normal performance for human cognition.

• High Productivity Computing Architecture. ($ 10.000 Million)
  - Identify application requirements.
  - Initiate productivity benchmarks and stressmarks.
  - Develop innovative programming models and virtual machine forms.
  - Explore scalable computing programming and profiling techniques.

• Robust High Assurance Systems. ($ 6.800 Million)
  - Establish cost/benefit framework for security and dependability properties and quantitative methods for reasoning about benefits/risks of selected properties.
  - Develop basic suite of secure, robust Quality of Service enforcement mechanisms and management services.
  - Demonstrate algorithms and techniques for providing controlled sharing of medium access, providing traffic cover and patterns.

(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 June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E, Project ST-22					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Software Engineering Technology ST-22	16.630	17.839	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) Software is key to meeting DoD's increasing demand for high quality, affordable, and timely national defense systems. There is a critical need to rapidly transition state-of-the-art technology and best practices to improve the acquisition, engineering, fielding, and evolution of software-intensive DoD systems. This project funds the technology transition activities of the SEI at Carnegie Mellon University. The SEI is a Federally Funded Research and Development Center (FFRDC) sponsored by the Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics). It was established in 1984 as an integral part of the DoD's software initiative to identify, evaluate, and transition high leverage technologies and practices, and to foster disciplined software engineering practices by DoD acquisition and life cycle support programs and within the industrial base where the bulk of defense software is produced. The Institute works across government, industry, and academia to: (1) improve current software engineering activities from both management and engineering perspectives; (2) facilitate rapid, value-added transition of technology into practice; and (3) evaluate and calibrate emerging technologies to determine their potential for improving the evolution of software-intensive DoD systems.

(U) The SEI enables the exploitation of emerging software technology by bringing engineering discipline to software acquisition, development, and evolution. The SEI focuses on software technology areas judged to be of the highest payoff in meeting defense needs. FY 2000 focus areas were: Technical Engineering Practices (including Survivable Systems practices, Architecture-centered Software Engineering, and Commercial Off-The-Shelf (COTS)-Based Software Engineering); Enhanced Software Management Capabilities (including personal and team software development processes and Capability Maturity Model Integration (CMMI)); and accelerating Adoption of High Payoff Software Technologies.

(U) Beginning in FY 2002, the funding for the Software Engineering Institute (SEI) has been transferred from DARPA to the Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics) under PE 0603781D8Z. This transfer aligns the funding authority with the program management oversight responsibilities for the SEI program. In keeping with this decision, FY 2001 SEI funds were transferred via Internal Reclassification Reprogramming action.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E, Project ST-22

(U) **Program Accomplishments and Plans:**

(U) **FY 2000 Accomplishments:**

- Software Technical Engineering Practices. ($ 9.832 Million)
  - Defined and piloted a method for survivable network technology analysis. Developed security self-evaluation method and training. Version 1 of product line acquisition guidelines and courses made available for use by DoD. Courses for training software engineers in the development of COTS-based systems were made available. DoD-based data on the benefits and costs of architecture analysis methods were made available.

- Software Engineering Management Practices. ($ 4.370 Million)
  - Updated and released Capability Maturity Model Integration (CMMI) training, assessment and other products based on Government and industry use and feedback. Data made available showing the benefits, costs, and appropriate conditions for use of Team Software Process.

- Adoption of Software Technologies. ($ 2.428 Million)
  - Developed guidebook for introducing technology change into organizations. Developed additional guidance for use of metrics in software acquisition and development. Continued to provide software measurement support to all initiative work to ensure performance measures were established. Provided transition planning and measurement support to SEI maturation and transition activities.

(U) **FY 2001 Plans:**

- Software Technical Engineering Practices. ($ 10.450 Million)
  - Establish techniques for modeling and predicting survivability attributes of systems while they are under development. Exemplar architectures for survivable systems will be in use by DoD and industry. Standard COTS evaluation practices will be defined and in use to support the development of COTS-based systems.

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- Software Engineering Management Practices. ($ 4.150 Million)
  - Support rollout and widespread use of integrated Capability Maturity Model (CMM) models; extend models to additional disciplines; document benefits and costs of using the integrated models; and prepare for revision of models based on actual experience in their use.

- Adoption of Software Technologies. ($ 3.239 Million)
  - Provide transition planning and measurement support to SEI maturation and transition activities.

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

- Program transferred to OUSD (AT&L).

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

- Not Applicable.

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

- Not Applicable.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)									DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Computing Systems and Communications Technology PE 0602301E, Project ST-24				
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Information Assurance and Survivability ST-24	60.589	84.241	77.738	85.800	64.500	64.000	64.000	64.000	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) An in-depth review of some of the Information Assurance and Survivability technology programs was conducted in FY 2000. The review resulted in a recasting of some programs to improve responsiveness to military operational information assurance and survivability needs. These recast programs will develop information assurance and survivability technologies to meet DoD needs and demonstrate the technologies in DoD systems.

(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.

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(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 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 situation 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.

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(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Autonomic Information Assurance. ($ 11.650 Million)
  - Identified response selection techniques for effectively handling broad classes of unknown attacks.
  - Investigated impacts and effects of dynamic response.
  - Designed active techniques for trace-back and automated response.

- Cyber Command and Control. ($ 7.588 Million)
  - Developed initial situation analysis techniques to derive strategic attack hypotheses.
  - Prototyped dynamic retasking of sensors to acquire missing situation information.
  - Developed capabilities for analysis and execution of directly controlled strategic response elements.

- Strategic Intrusion Assessment. ($ 11.353 Million)
  - Completed initial design for hierarchical reporting structure for intrusion detection systems.
  - Developed experimental methods for filtering events of purely local significance.
  - Developed common framework for linking intrusion assessment and response components.
  - Developed workflow model supporting dynamic response capability.

- Intrusion Tolerant Systems. ($ 12.223 Million)
  - Demonstrated practical digital integrity mark technology and information dispersal to facilitate recovery and verification of important data characteristics in large electronic image files.
  - Developed and demonstrated several promising execution monitoring prototype tools and techniques to significantly reduce the likelihood of malicious mobile code from compromising data integrity and confidentiality.
  - Identified mechanisms that rapidly distinguish intact and corrupted programs through automated verification of proof-carrying code.
  - Demonstrated a framework for perpetually available information systems that guarantee the survivability of information under malicious attacks or component failure.

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- Fault Tolerant Networking. ($ 10.484 Million)
  - Adapted fault tolerance techniques to the networking environment balancing redundancy for availability with security requirements.
  - Investigated user capability-based resource allocation mechanisms.
  - Demonstrated "push-back" techniques for denial-of-service attacks.
  - Exploited active network technology for attacker fencing.

- Dynamic Coalitions. ($ 6.991 Million)
  - Investigated languages and tools for specification and analysis of complex policies and translation into enforcement mechanisms.
  - Augmented existing Public Key Infrastructure (PKI) capabilities with protocols for rapid revocation of coalition member credentials.

- Computer Security. ($ 0.300 Million)
  - Implemented and tested a combination of robust elements to achieve high reliability for mission critical computer systems.

(U) FY 2001 Plans:

- Autonomic Information Assurance. ($ 17.996 Million)
  - Develop autonomic response architecture.
  - Identify promising assessment methodologies for more effective evaluation of very large information infrastructures.
  - Develop scalable models of very large information infrastructure.
  - Complete 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.
  - Transfer promising technologies for use by the Fault Tolerant Networking (FTN), Cyber Panel, and OASIS programs in FY 2002 and complete closeout of remaining Autonomic Information Assurance technologies.

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- Cyber Command and Control/Strategic Intrusion Assessment. ($ 30.552 Million)
  - Merge 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 focus technologies toward a coherent cyber attack monitoring and response management system.
  - Develop correlation and analysis algorithms to detect and track complex multi-phase or large-scale cyber attacks.
  - Develop 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.
  - Develop algorithms for evaluating and executing coordinated defensive actions and attack responses, automatic and human-initiated, across a large distributed system.
  - Transfer promising technologies for use by the Cyber Panel, Survivable Global Information Grid (GIG) and OASIS programs in FY 2002 and complete closeout of remaining Cyber Command and Control/Strategic Intrusion Assessment technologies.

- Intrusion Tolerant Systems. ($ 3.798 Million)
  - Transfer promising technologies for use by the Organically Assured and Survivable Information Systems (OASIS) and Cyber Panel programs in FY 2002 and closeout activities on remaining projects.
  - Investigate market-based and value-based resource allocation mechanisms.

- Fault Tolerant Networking. ($ 23.834 Million)
  - Develop techniques to isolate corrupted or malicious network entities.
  - Investigate progress-based network resource allocation mechanisms to prevent denial-of-service.
  - Investigate trust-chain techniques for network resource allocation and protection against denial-of-service.
  - Design active techniques for traceback and automated response.
  - Transition Secure Border Gateway Protocol (SBGP) to COTS router vendors and establish necessary Public Key Infrastructure (PKI) that provides basic authentication of and authorizations for potential users.
  - Develop 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 must address the improvement of the robustness of the DNS, using an arbitrary mesh of trust.

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- Dynamic Coalitions. ($ 8.061 Million)
  - Prototype protocols for negotiation of policies across coalition members.
  - Create methods for fast sender authentication, scalable key distribution for creation and rekeying of coalitions.
  - Extend existing PKI capabilities with protocols for cross certification of coalition members.

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

- Fault Tolerant Networks. ($ 37.624 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.
  - Complete parallel field evaluation of infrastructure assessment methodologies.

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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). ($ 7.000 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. ($ 8.781 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) 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 Computing Systems and Communications Technology PE 0602301E, Project ST-28					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Asymmetric Threat ST-28	0.000	26.884	58.087	50.700	49.500	45.000	50.000	55.000	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 suite of tools to better detect and prevent attacks upon our critical DOD infrastructures. The 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).

(U) The Human Identification at a Distance (HumanID) program objective is to develop automated multi-modal, multi-biometric surveillance technology for identifying humans at a distance as an enabler for force protection and early warning against an Asymmetric Threat. HumanID seeks to improve individual biometric technologies and develop methods for fusing biometric signatures from multiple sensors for multi-range, round-the-clock processing. HumanID focuses on multi-modal fusion of different biometrics techniques with focus on body parts identification, face and human kinematics, with biometric signatures acquired from video, infrared and multi-spectral sensors, and configurations of networked cameras. Biometric techniques will be examined as a function of multiple ranges and presentation time. The goal of this program is to identify humans as

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unique individuals (not necessarily by name) at a distance, at any time day or night, during all weather conditions, with non-cooperative subjects, possibly disguised and alone or in groups. An outgrowth of the Image Understanding for Force Protection effort, the HumanID program was funded under Project ST-11 in FY 2000.

(U) The objective of the Evidence Extraction and Link Discovery (EELD) program is to develop a suite of technologies to automatically extract evidence from vast amounts of unstructured textual data, discover relevant relationships among those extracted facts to provide advance warnings of potential terrorist activities, and learn patterns corresponding to models of significant activities. Recent advances in language understanding software will be exploited to provide a capability to automatically extract facts from textual message, 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 techniques will be extended to enable learning and evaluation of patterns comprised of relationships among people, organizations, activities, and scenarios.

(U) The Wargaming the Asymmetric Environment (WAE) program will provide the ability to conduct real time operational wargaming in an asymmetric environment. Current wargames are general-purpose situation-response models that do not take into account the asymmetric threat. This project will inject adversarial behavior models into a multi-sided wargame. WAE seeks to develop operational wargaming tools that allow multi-dimensional asymmetric environments and intelligent stakeholders (adversary, friendly and neutral). These will advance current techniques, which are sequential, contain generic behavior models and are limited by scripted adversary play. This will significantly increase the commander and analyst's ability to make operational decisions and develop collaborative gaming techniques against all adversaries simultaneously.

(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. The goal of the Bio-Surveillance program is to 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. This project requires the development and integration of diverse biological modeling and information systems technologies. 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.

(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 physical infrastructure networks based upon the interdependencies that exists among them.

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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 infrastructure networks separately using high fidelity commercial simulations, but cannot model their nonlinear and complex interdependencies. 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 (QoS, 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.

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

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

- Not Applicable.

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

- Human Identification at a Distance. ($ 11.502 Million)
  - Develop a fixed site, force protection approach to identifying humans at a distance.
  - Use specific service sites as prototype models.
  - Develop evaluation methodologies and independent evaluations on human identification techniques candidates.
  - Develop and assess validity of current and future technologies to meet the proposed system needs.
  - Demonstrate automated Human Identification at a Distance under outdoor lighting conditions.

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- Evidence Extraction and Link Discovery. ($ 9.145 Million)
  - Identify candidate unclassified and classified document collections from which asymmetric threats can be detected.
  - Analyze language characteristics of relevant document collections.
  - Initiate collection of document collections to use as basis for technology developments.
  - Evaluate applicability of promising information extraction and link discovery techniques.
  - Select candidate information extraction techniques and approaches for development.
  - Select candidate link discovery techniques for development.
  - Select candidate pattern learning techniques for development.

- Wargaming the Asymmetric Environment. ($ 6.237 Million)
  - Develop and cross validate asymmetric model ontology with open and classified data.
  - Statistically test advanced reasoning techniques for applicability to asymmetric threats.
  - Develop initial model set of specific known asymmetric threats.
  - Develop challenge problems and associated test criteria.
  - Perform predictive modeling experiments.

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

- Human Identification at a Distance. ($ 15.850 Million)
  - Incorporate multiple sensors and multiple biometric approaches into new capabilities.
  - Consider the range, accuracy, and reliability of combinations of facial features, gait, and other key identification techniques.
  - Determine the critical factors that affect performance of multi-modal techniques.
  - Demonstrate multi-modal Human Identification at a Distance capabilities.

- Evidence Extraction and Link Discovery. ($ 9.398 Million)
  - Develop candidate information extraction techniques for extracting facts from text messages, news reports and web pages.
  - Specify models of asymmetric threat scenarios.

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- Develop candidate link discovery techniques using extracted facts and additional data sources.
- Develop candidate pattern learning techniques for models of asymmetric threat scenarios.
- Demonstrate ability to extract relational facts.

- Wargaming the Asymmetric Environment. ($ 16.839 Million)
  - Conduct generalization experiments.
  - Establish operational testbeds in conjunction with one or more transition partners.
  - Empirically determine classes of asymmetric threats.
  - Generalize predictive models from individual to classes of asymmetric threats.
  - Continue to develop and validate threat specific modeling techniques.
  - Expand development to include civilian model.

- 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.
  - Develop computer simulation environment to emulate bio-terrorist events and impacts on agricultural, animal and human populations.

- Endstate. ($ 2.000 Million)
  - Investigate reduced order modeling techniques for cross network effects prediction.
  - Develop methods for generating and refining courses of action and control options.
  - Identify technology for modeling adversary work-arounds.
  - Investigate methods for maintaining timely and accurate network state estimates.

- DefenseNet. ($ 6.000 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).

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– Develop several prototype networks, based upon current commercial optical and electro-optical components to test the security /performance trade-off space.

(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 Embedded Software and Pervasive Computing PE 0602302E, R-1 #15

COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	30.000	52.407	75.561	62.000	65.700	50.000	60.000	60.000	Continuing	Continuing
Deeply Networking Systems AE-01	5.405	12.214	20.656	25.000	30.000	32.000	42.000	42.000	Continuing	Continuing
Software for Autonomous Systems AE-02	16.873	14.171	27.205	25.000	21.983	18.000	18.000	18.000	Continuing	Continuing
Software for Embedded Systems AE-03	7.722	17.803	27.700	12.000	13.717	0.000	0.000	0.000	0.000	N/A
Gigabyte Applications AE-04	0.000	8.219	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

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

(U) The goal of the Embedded Software and Pervasive Computing program is to greatly extend the reach and effectiveness of networked computation. It is funded in the applied research budget activity because it is pursuing network and software research to facilitate the "deep networking" of computers, such as those embedded within DoD platforms and weapons. It will also conduct research to greatly increase the autonomy of those systems, so as to promote the human role from that of operator to supervisor.

(U) The Deeply Networked Systems 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 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.

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(U) The Software for Autonomous Systems project develops software to enable predictable, safe, and cooperative operation of a 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 software agents (knowbots) that can range over cyberspace performing information services, including the capability to negotiate for and assign selected resources. Further, some autonomous systems should be able to learn and adapt to change and uncertainty while improving with experience.

(U) The Software for Embedded Systems project develops a new class of software to deal with the processing of physical world information by networked 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. For example, cheap, smart micro-sensors can be deployed quickly in large quantities in the battlefield to perform new monitoring and control functions; and a host of sensors can be attached to warfighters and assets to autonomously monitor safety and health information, and equipment condition. Funding will end in FY 2004.

(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 will be developed with technologies that allow ultra high-throughput, sustained low-latency data delivery and processing. Funding ends in FY 2001.

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

	FY2000	FY 2001	FY 2002
Previous President's Budget	30.000	69.282	105.196
Current Budget	30.000	52.407	75.561

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(U) Change Summary Explanation:

FY 2001	Decrease reflects congressional program reduction, Section 8086 reduction and government-wide rescission.
FY 2002	Decrease reflects rephasing of programs following the FY 2001 congressional program reduction and reprioritization of Agency requirements. Specifically, robotic software activities have been reduced and the Gigabyte Applications project has been terminated.

(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 Embedded Software and Pervasive Computing PE 0602302E, Project AE-01					
COST (In Millions)	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Deeply Networking Systems AE-01	5.405	12.214	20.656	25.000	30.000	32.000	42.000	42.000	Continuing	Continuing

(U) Mission Description:

(U) Extending DoD's ability to monitor and control the physical environment 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 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 networking of embedded and autonomous devices creates additional requirements for: embedded technologies that can achieve drastic reductions in costs while being compatible with a wide range of network and computation media; flexible mechanisms for naming, addressing, configuring and administering communication and computation resources; and system design technology which shifts the emphasis from static verification and validation to dynamic behavior guarantees. These challenges are addressed in the Networked Embedded Systems component of this project.

(U) Close coupling of information processing with physical processes demands new technology for the integrated modeling of software and physical systems. These models will enable designers to capture complex cross cutting physical constraints that the embedded software must satisfy. The Model-Based Integration of Embedded Software component of this project will use integrated models to analyze and verify the aggregate behavior of software and physical processes, and to automatically customize and integrate system components.

(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; and autonomous system behavior requires the middleware components and frameworks to be capable of reflection to adapt robustly to quantifiable changes in environmental

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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) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Networked Embedded Systems. ($ 5.405 Million)
  - Investigated new modeling methods capturing physical constraints in embedded systems such as avionics and vetronics.
  - Developed customizable modeling tools that can be rapidly adjusted to different modeling views and application domains.
  - Investigated new generation technology with capability to configure, customize and synthesize software directly from models.

(U) FY 2001 Plans:

- Model-Based Integration of Embedded Software. ($ 12.214 Million)
  - Develop modeling tools that can manage overlapping modeling views.
  - Investigate methods for the mathematical modeling and composition of model-based software generators.
  - Develop customizable frameworks for embedded software.
  - Demonstrate the rapid synthesis of embedded systems using customizable frameworks and model-based generators.
  - Develop meta-modeling techniques for integrating different COTS analysis tools into a single tool environment.

(U) FY 2002 Plans:

- Model-Based Integration of Embedded Software. ($ 13.656 Million)
  - Develop methods to integrate different models of concurrency.
  - Develop methods for efficient run-time checking for models of concurrency.
  - Demonstrate ability of propagating constraints among modeling views.
  - Investigate methods to integrate interdependent modeling views using high-level multiple view modeling languages.

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- Demonstrate ability to compose multiple view models with interdependent modeling views.
- Develop hybrid modeling and analysis techniques for synchronous embedded systems.
- Develop generic components for model-based generators.
- Develop and demonstrate techniques for the mathematical modeling and formal verification of generators.
- Develop formal models for synchronous embedded software frameworks.
- Demonstrate Open Experimental Platform for embedded avionics applications and for vehicular electronics applications.

• Adaptive Reflexive Middleware Systems (ARMS). ($ 7.000 Million)
  - Develop adaptive protocols, algorithms, patterns, and tools for distributed resource management.
  - Develop meta-programming policies and mechanisms to customize QoS-enabled middleware services and applications.

(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 Embedded Software and Pervasive Computing PE 0602302E, Project AE-02					
COST *(In Millions)*	FY 2000	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	16.873	14.171	27.205	25.000	21.983	18.000	18.000	18.000	Continuing	Continuing

(U) Mission Description:

(U) This project develops software to enable predictable, safe, and cooperative operation of a 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 software agents (knowbots) that can range over cyberspace performing information services, including the capability to negotiate for and assign selected resources. Further, some autonomous systems should be able to learn and adapt to change and uncertainty while improving with experience.

(U) Autonomous systems will enable revolutionary, asymmetric military capabilities, such as the ability to autonomously convey military payloads (both lethal and non-lethal) to any portion of the battlefield without requiring human operators and the ability to autonomously retrieve, process and deliver information.

(U) The Common Software for Autonomous Robotics component of this project will develop a combination of critical, enabling software technologies that can be reused across a wide range of mobile autonomous robotic systems.

(U) The Software Enabled Control component will leverage increased processor and memory capacity to vastly increase the user's ability to maintain control over mobile devices through the development of novel techniques, such as: predictive mode changes, dynamic control scheduling, composable coordinated control, and dynamic sensor and actuator allocation.

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

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

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

- Common Software for Autonomous Robotics. ($ 6.734 Million)
  - Developed architectures for the integration of deliberative, reactive and learning behaviors, including knowledge representations.
  - Demonstrated alternative approaches to off-line learning.
  - Demonstrated rapid sensor-motor mapping.
  - Demonstrated “engineered” behaviors.
  - Demonstrated “statistical” control.

- Software Enabled Control. ($ 6.950 Million)
  - Specified architecture for a hybrid control system that synthesizes the control law approach with computationally-enabled mode logic scalable to very large state spaces of 100K+ states.
  - Developed active transition control and joint mode logic/control law designs.
  - Designed services for active model creation, augmentation and query.

- Agent Based Negotiation. ($ 3.189 Million)
  - Developed framework for bottom-up organization of autonomous software.
  - Defined strategy for tasking and consolidation of responses from large numbers (thousands) of software agents with minimal human intervention.

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

- Common Software for Autonomous Robotics. ($ 4.234 Million)
  - Perform experimental evaluation of networking protocols for distributed robot controls that are more energy efficient than conventional implementations.

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- 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. ($ 8.970 Million)
  - Complete alpha-level prototype implementation of multi-mode control architecture and framework.
  - Develop predictive active model framework.
  - Develop parametric predictive and adaptive control frameworks.
  - Complete multi-level, multi-modal advanced design tools.

- Agent Based Negotiation. ($ 0.967 Million)
  - Complete prototype demonstration of autonomous software's ability to utilize negotiation in logistics scenario.

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

- Common Software for Autonomous Robotics. ($ 7.914 Million)
  - Demonstrate energy-saving protocols with at least 70 percent savings over conventional protocol implementations.
  - Integrate developmental network protocols into selected Distributed Robots platforms.
  - Evaluate developmental network protocols using the representative robot platforms in representative mission scenarios.
  - Integrate natural, implicit communications modes into selected Distributed Robots platforms.
  - Evaluate implicit communications modes using selected Distributed Robots platforms in representative mission scenarios.
  - Evaluate "world-embedded" user interfaces.
  - Investigate cooperative approaches to achieving critical situational awareness in tactical environments.
  - Assess coordination and fusion of multiple sensing modalities with computational processing to achieve real time operation.

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- Software Enabled Control. ($ 19.291 Million)
  - Develop Open Control Platform (OCP) services for control coordination for unmanned avionics (e.g., atomic mode switch; event generation; discrete blocking, enabling, forcing).
  - Configure OCP prototype for three-level hybrid (discrete + continuous) control.
  - Integrate hybrid Fault Detection Identification Reconfiguration (FDIR) 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 concept and instrumentation technology for flight qualification of single-system multi-modal control.
  - Develop system concept for high-confidence authority management for hybrid control.
  - Develop theoretical framework for robust hybrid control.
  - Integrate OCP on lab vehicle.
  - Conduct simulation experiments for two-level control; conduct flight experiment.
  - Develop baseline sensor and actuator resource services for unmanned aerial platforms.

(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 Embedded Software and Pervasive Computing PE 0602302E, Project AE-03

COST *(In Millions)*	FY 2000	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	7.722	17.803	27.700	12.000	13.717	0.000	0.000	0.000	0.000	N/A

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

(U) This project develops a new class of software to deal with the processing of physical world information by networked 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. For example, cheap, smart micro-sensors can be deployed quickly in large quantities in the battlefield to perform new monitoring and control functions; and a host of sensors can be attached to warfighters and assets to autonomously monitor safety and health information, and equipment condition.

(U) Harnessing the full potential of micro-sensors and embedded devices requires addressing new information technology challenges. Networking these untethered devices creates new requirements on hardware and software, including rapid self-assembly, timely acquisition, processing and exchange of sensor data, and energy efficient operation. Accurate identification of events and collection of information require new ways of cooperation among these devices to process physical world signals, and to integrate information in the network. Additionally, remote querying and accessing data collected by the sensor net should be simple, with easy to use interfaces.

(U) This project will build on Software and Networking R&D activities, extending and specializing them to geographically distributed micro-sensor networks. A major challenge is the development of software technologies that spans a variety of sensor nets, on ground and water, on buildings and bodies. Another challenge is to design reliable networked embedded systems retaining only supervisory control, while automating traditional "in-the-loop" tasks. The sensor tasking, data collection, integration and analysis must be fully automated to enable operation within time constraints far shorter than could be achieved by human operators.

(U) Complex software systems must be able to reconfigure and evolve themselves dynamically, while operating. This project will develop the dynamic gauges or measures of composability necessary to enable software components from any source to support assured applications under the Dynamic Assembly for Systems Adaptability, Dependability and Assurance (DASADA) program. Outputs from this program will ensure that the critical properties of complex, heterogeneous software systems are maintained during and after composition, adaptation and deployment.

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(U) **Program Accomplishments and Plans:**

(U) **FY 2000 Accomplishments:**

- Large Scale Networks of Sensors. ($ 7.722 Million)
  - Identified diffusion-based approaches to networking, and aggregation and distribution of information from large numbers of multi-taskable sensor nodes.
  - Explored low-latency system designs; developed experimental platform and simulation capability.
  - Developed methods for collaborative signal processing and information integration.
  - Investigated use of declarative interfaces for tasking and querying of networked embedded systems; developed experimental prototype based on relational database query technology and lightweight operating environment.

(U) **FY 2001 Plans:**

- Large Scale Networks of Sensors. ($ 12.890 Million)
  - Implement experimental prototype supporting automated aggregation and distribution of sensor derived information involving at least 50 nodes and 100 sensors.
  - Investigate methods for efficient interoperation of fixed and mobile sensors.
  - Demonstrate multi-node sensor network software and benefits of collaborative signal processing for military operations such as fast moving target detection and urban operations.
  - Prototype demonstration using declarative interfaces for tasking and querying of multi-taskable sensor networks.

- Dynamic Assembly for Systems Adaptability, Dependability and Assurance (DASADA). ($ 4.913 Million)
  - Conduct preliminary demonstrations of dynamic software component composability with multiple standard communication (e.g. Distributed Component Object Model (DCOM), Common Object Request Broker Architecture (CORBA), Distributed Computing Environment (DCE)) or Structuring (e.g., Extended Markup Language (XML), Resource Description Framework (RDF), Document Object Model (DOM)) infrastructures.

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(U) **FY 2002 Plans:**

- Large Scale Networks of Sensors. ($ 16.818 Million)
  - Optimize embedded node processing and protocols to achieve minimum latency in military sensor networks.
  - Develop and implement techniques for obtaining application specific quality of service that accommodates needed mission variations among latency, power, scalability, and reliability.
  - Implement techniques for rapid self-management for ad hoc and dynamic sensor networks.
  - Implement protocols for effective interoperation between fixed sensor devices and mobile devices on robots, vehicles, UAVs, and personnel.
  - Implement distributed algorithms for sensor coverage, and easy graphical user interface, to support real-time incremental deployment in battlefield contexts.
  - 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 techniques for micro-databases for storing, accessing, and processing in a sensor network.
  - Implement technology for dynamic tasking, querying, multi-tasking, and rapid specialization, customization, and reconfiguration of software during operation, through mobile code technology.
  - Complete architecture specification to support integrated software and operation of sensor devices with diverse capabilities: from smart dust or miniature motes to higher functionality devices with multi-modal on-board sensors.
  - Complete modeling and simulation capability scalable to large sensor networks.
  - Develop engineering methods 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.
  - Field demonstrations and joint experiments with DoD agencies including Marines, Army, Air Force and the Navy, to show new operational capabilities of embedded distributed micro-sensor software for accurate and fast tracking of mobile targets, and detection and classification of threats in complex battlefield scenarios including MOUT and urban warfare.
  - Engage Intelligence, Emergency, and National Guard end users in joint experimentation to demonstrate new paradigms for sensing threats.

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- Dynamic Assembly for Systems Adaptability, Dependability and Assurance (DASADA). ($ 10.882 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.
  - Conclude Phase I, technology refinement and integration projects.
  - Identify most promising technologies for experiment transition.

(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 Embedded Software and Pervasive Computing PE 0602302E, Project AE-04					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Gigabyte Applications AE-04	0.000	8.219	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) This 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 will be developed with technologies that allow ultra high-throughput, sustained low-latency data delivery and processing. Funding will end in FY 2001.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Not Applicable.

(U) FY 2001 Plans:

- Ultra-High Performance Heterogeneous Flow-Based Communications. ($ 4.100 Million)
  - Develop software and physical interfaces that can adapt or be programmed to support diverse link protocols, symbol rates and signaling technologies.
  - Demonstrate gateway technology that can segregate long flows from short flows.

- Gigabit Multi-Link. ($ 4.119 Million)
  - Demonstrate an order of magnitude increase in wireless spectral efficiency for non-mobile end nodes.
  - Demonstrate adaptive multi-link coding technique to enhance immunity to degradations due to mobility or environmental (weather, obstruction) changes.

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(U) **FY 2002 Plans:**

- Not Applicable.

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

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
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 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	124.272	166.769	140.080	140.000	156.000	169.000	169.000	169.000	Continuing	Continuing
Biological Warfare Defense Program BW-01	124.272	166.769	140.080	140.000	156.000	169.000	169.000	169.000	Continuing	Continuing

(U) Mission Description:

(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.

(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).

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(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 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) Mission effectiveness requires rapid, correct medical responses to biological weapon threats or attacks. This project will provide comprehensive protocols to protect or treat combatants by using current and emerging biological countermeasures. It will provide accelerated situational awareness for biological warfare events by detecting exposure to agents through an analysis of casualty electronic theater medical records and will locate and determine the most effective logistical support for providing appropriate treatment and pathogen-specific resources required to mitigate effects of the attack.

(U) DARPA is working with a number of governmental organizations to exploit recent advances in high throughput genetic sequencers to obtain complete genetic information on a number of important pathogens and their non-pathogenic nearest neighbors. This will allow 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

(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

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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. 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 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.

(U) DARPA sponsored a one-year investigation in FY 2000 of a technology that uses a new material (aerogel) for the collection of agents of biological origin. Aerogel is a term used to describe very low-density, highly porous, polymeric materials that provide a highly efficient, lightweight collection medium for airborne particles. DARPA is also sponsoring a proof-of-principle program in FYs 2000 and 2001 evaluating the potential of delivery immune system enhancement via inhalation for defense against BW threats.

(U) The DNA Chip Technology Research program is a one-year effort to investigate 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 will also explore non-traditional approaches to desalination.

(U) Lastly, an additional $13 million was appropriated for BW counter terrorism response in FY 2001. This activity fell outside the scope of DARPA's charter and was therefore reprogrammed (IR 1415) to the DoD Chemical and Biological Defense Program (PE 0602384BP) in January 2001 for continuation of their efforts initiated in FY 2000.

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

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

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- Anti-Virals/Immunizations. ($ 16.999 Million)
  - Identified broad-spectrum strategies with potential for immunomodulatory activity against multiple pathogens.
  - Developed technologies for rapid design and development of new vaccines against novel pathogens.
  - Demonstrated (in-vitro) candidate anti-viral, small molecule therapeutics for selected targets.
  - Demonstrated (in-vivo) the efficacy of anti-viral peptides derived from hematopoietic stem cells.

- Anti-Bacterials/Anti-Toxins. ($ 17.065 Million)
  - Developed (in-vitro) broad spectrum, superantigenic, anti-toxin antagonists and vaccines.
  - Validated the efficacy (in-vivo) of antagonists to toxin receptors, toxin catalytic sites, and cellular platforms for toxin destruction.
  - Demonstrated (in-vivo) the efficacy of a broad-spectrum bacterial antagonist.
  - Used gene-shuffling techniques to generate molecules screened for superantigenic properties.

- Multi-Purpose. ($ 15.972 Million)
  - Explored concepts for therapeutics against bioregulators and other mid-spectrum agents.
  - Identified primary harmful immune responses to biological warfare (BW) agents.
  - Explored concepts for optimizing human immune response to BW agents.
  - Demonstrated in laboratory animal models the ability of modified stem cells to prevent disease.
  - Identified monomeric and dimeric DNA and RNA binding molecules as novel countermeasures against multiple pathogens.
  - Identified polyvalent inhibitors for inhibiting pathogens on the surface of target cells in-vivo.

- External Protection. ($ 17.137 Million)
  - Developed decoy molecules that prevent the adhesion of multiple pathogenic toxins or viruses in-vivo.
  - Demonstrated (in-vivo) a non-specific surfactant agent to neutralize biological threat agents.
  - Demonstrated initial performance of a prototype device for the purification of water contaminated with BW agent simulants.
  - Explored high throughput methods for the purification of contaminated air.
  - Demonstrated effectiveness of specific personnel protective toxin and pathogen neutralization strategies against virulent biological agents.

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- Advanced Diagnostics. ($ 15.092 Million)
  - Continued identification and development of probes to be used in diagnosis systems and began testing of probe panels in the laboratory.
  - Developed sample preparation techniques to optimize speed, accuracy, and reliability of diagnosis.
  - Identified promising strategies for rapid detection based on bodily responses or other biomarkers (including cytokines) to provide early indication of infection or exposure including non-invasive early detection of disease [e.g., nitric oxide in exhaled breath].
  - Determined feasibility of engineering red blood cells to detect and signal pathogen presence in the body.
  - Determined feasibility of rapid single molecule DNA sequencing for accelerated patient diagnosis.
  - Explored concepts for diagnosing patients for bio-regulator and other mid-spectrum agent attack.

- Sensors. ($ 21.507 Million)
  - Continued building and characterizing first-generation prototype of live agent biochip sensor.
  - Completed development of air sampling technology for airborne biological material.
  - Continued development of effective and rapid chip-reading capability with enhanced sensitivity.
  - Continued the development of unique signatures for bio-agents in mass spectrometry identification.
  - Continued the development of biosensor technology for next-generation (bioengineered) threat agents.
  - Developed methods for identifying bioregulator-based BW agents.
  - Explored options (e.g., training, genetic engineering, etc.) for the use of invertebrates in the detection of BW agents and associated chemicals.
  - Constructed cell and tissue engineered configurations to enhance optical or electrical signal output from the sensor.
  - Investigated optimal system designs for deployment of a single cell and tissue-based biosensor, which incorporated environmental sampling, microfluidics, and automated detection.
  - Evaluated cell and tissue based informatics from temporal and spatial signals in cell and tissue-based sensors.
  - Explored shelf-stabilization strategies for cells and tissues.
  - Began development and optimization of bio-agent sensors and other technologies for use in building protection.
  - Evaluated the capability to predict flow of airborne bio-agents in and around buildings (fate and transport).
  - Began the development of neutralization and decontamination techniques appropriate to buildings.

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- Genetic Sequencing of Biological Warfare Agents. ($ 4.000 Million)
  - Developed inventory of DoD-relevant BW agent pathogens requiring sequencing.
  - Determined best methods for rapidly sequencing biological warfare pathogens and related species and strains.
  - Began development of database mining techniques to find new targets for sensors, diagnostics, and therapeutics.
  - Initiated sequence analysis of four BW threat agents – *Rickettsia typhi*, *Coxiella burnetti*, *Burkholderia mallei, and Brucella suis* – and orthopox virus variants.

- Consequence Management. ($ 10.000 Million)
  - Developed distributed BW consequence management smart checklists for automatic pull and push of required information.
  - Continued development of Enhanced Consequence Management Planning and Support System (ENCOMPASS) software toolkit.
  - Developed automated playbook/checklists for BW attacks and incorporated Incident Command System capabilities.
  - Demonstrated use of ENCOMPASS for OCONUS air base force protection against a BW attack.
  - Demonstrated use of playbooks and automated checklists for training BW incident responders.
  - Integrated Consequence Assessment Tool Set (CATS) with Electronic Watchboard using the ENCOMPASS architecture.

- Asymmetrical Protocols for Biological Warfare Defense. ($ 3.500 Million)
  - Developed recommendation regarding whether cytokines are promising for further inhalational formulation development.

- Aerogel. ($ 3.000 Million)
  - Investigated capture efficiency as a function of aerogel porosity.
  - Continued the development of aerogel coatings with greater flexibility and adherence to mass spectrometer tape.
  - Developed tape manufacturing technology.
  - Tested collection efficiencies of a number of different aerogel compositions.

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(U) **FY 2001 Plans:**

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

- Anti-Bacterials/Anti-Toxins. ($ 20.730 Million)
  - Demonstrate surface expression of specific enzyme molecules for the rapid inactivation of various pathogens.
  - Demonstrate (in-vivo) the efficacy of a broad-spectrum bacterial pathogen antagonist.
  - Validate (in-vivo) broad spectrum, superantigenic, anti-toxin antagonists and vaccines.
  - Demonstrate (in-vivo) efficacy of broad spectrum, superantigenic, antitoxin antagonists and vaccines.

- Multi-Purpose. ($ 21.833 Million)
  - Develop therapeutic strategies against bioregulators and other mid-spectrum agents.
  - Demonstrate synthetic polymer complements for pathogenic antigens and virulence factors.
  - Develop therapeutic strategies for minimizing harmful immune responses to biological warfare agents.
  - Demonstrate (in-vitro) the efficacy of monomeric and dimeric DNA and RNA binding molecules as novel countermeasures against multiple pathogens.
  - Validate polyvalent inhibitors for blocking pathogens on the surface of target cells in-vivo.
  - Identify superantigens for broad protection against biological warfare agents with minimal side effects.
  - Validate (in-vivo) the efficacy of subcellular pathogen response imaging for rapid detection.
  - Validate technologies broadly applicable to enhance cellular therapeutics (delivery platforms) and virulence modulation (intracellular and inflammatory cascades).

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- External Protection. ($ 18.000 Million)
  - Develop a novel architectural approach for the manufacture of materials that are effective in blocking pathogens and limiting disease.
  - Demonstrate a non-aqueous advanced decontamination method.
  - Demonstrate a water purification system effective against a range of biological agents (including toxins and bioregulators).
  - Test initial performance of advanced sorbent materials for the purification of air contaminated with CW and BW agent simulants for individual protection.
  - Build and test a prototype air purification system for collective protection for a group of soldiers.
  - Begin testing of prototype protective system against non-virulent biological warfare agents, bio-toxins and regulators.

- Advanced Diagnostics. ($ 17.600 Million)
  - Test probe panels in relevant sample types including strategies for rapidly generating new/novel probes.
  - Demonstrate that sample collection and/or preparation techniques do not introduce artifacts.
  - Test, 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.
  - Develop the capability to diagnose exposure to bio-regulator and mid-spectrum agents.
  - Demonstrate, in the laboratory, the feasibility of engineering red blood cells to detect and signal pathogen presence in the body.
  - Evaluate the feasibility of additional strategies (e.g., exhaled breath) for direct identification or detection of infection without direct sample collection.
  - Demonstrate the ability to perform accelerated patient diagnosis using a rapid single molecule DNA sequencing technique in a model system.

- Sensors. ($ 24.056 Million)
  - Complete development and testing of first-generation prototype biochip sensor.
  - Continue the development of effective and rapid chip-reading capability with enhanced sensitivity and low false alarm rate.
  - Continue the development of advanced alternative technologies for live vs. dead bio-agent identification using peptides and other molecules.
  - Develop hierarchical biochip sensors.
  - Design and test techniques to replace antibody-based detection, such as short peptides, aptamers and lectins.

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- Design and test novel reporting/transduction techniques such as ion channels.
- Design and synthesize short peptide binding molecules for use in the detection of biological warfare agents.
- Evaluate and develop ion channel sensor systems for use in the detection of biological warfare agents.
- Evaluate methods for removing micro-encapsulation of disguised pathogens and/or sensing through the micro-encapsulation.
- Develop technologies required for next-generation miniature biological detectors including the use of microelectromechanical systems (MEMS), microfluidics, and mesoscopic-sized components.
- Evaluate false positive and false negative rates for systems of detectors using biomolecular cells or tissues.
- Exploit and/or mimic the olfactory sensors of biological systems for use in the detection of biological warfare agents.
- Demonstrate enhanced signal output from engineered cells and tissue based sensors and integrate information from these sensors with user interfaces for predictive responses.
- Engineer a deployable prototype cell and tissue sensor for field-testing.
- Evaluate sample collection technologies for cell and tissue sensors.
- Develop biosensor models and robust characterization protocols.
- Evaluate new resonant modes for biosensors.
- Investigate standoff techniques for trigger and identification.
- Develop concepts for sensors capable of detecting biological warfare agent production in underground facilities.
- Investigate critical design parameters for advanced biologically based BW sensor.
- Demonstrate use of organisms to collect chemical and biological warfare agents in the field.
- Develop and validate comprehensive performance model for time-of-flight (TOF) mass spectrometer detection of aerosolized live agents against clutter.
- Evaluate time-of-flight (TOF) mass spectrometer performance for counter-proliferation scenarios.
- Initiate the development, modeling, and validation of integrated sensor systems designed to meet detailed threat specifications.
- Evaluate novel concepts for warning systems, including stationary or mobile-networked surveillance systems.
- Explore a novel concept for universal BW probes as a possible foundation for a new sensor suitable for forensics, biomedical surveillance and environmental sensing and estimate performance against bacteria.
- Explore BW agent spectral signatures as a possible foundation for point, point-to-point and standoff BW sensors.
- Explore the use of social insects as BW agent collectors.

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- Bio/Chem Defensive Systems. ($ 10.000 Million)
  - Continue fate and transport model development in and around buildings and begin experimental evaluation.
  - Continue to develop decontamination techniques appropriate for structures.
  - Evaluate novel low-pressure-drop, broadband filter technologies.
  - Develop neutralization technologies for aerosolized agents.
  - Conduct hazard assessment for protection of military buildings from bio-chem attack; assess protection strategies.
  - Identify facilities, and identify/design the facility modifications required, for full-scale testing and evaluation of building-protection systems.
  - Evaluate concepts for novel protection systems, such as portal barriers.

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

- Consequence Management. ($ 6.000 Million)
  - Demonstrate Enhanced Consequence Management Planning and Support System (ENCOMPASS) management of multi-site BW incidents.
  - Demonstrate and field the use of ENCOMPASS for CONUS military force protection against BW attacks, i.e. Pacific Battlelab & Kernal Blitz Experiment.
  - Transition ENCOMPASS components to Initial Detection Units of the Air Force and to PACCOM, JFCOM, and Wilford Hall Medical Center.
  - Transition of ENCOMPASS components into Joint Chiefs of Staff Operations Center.

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

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

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

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

- Biological and Chemical Terrorism Response. ($ 13.000 Million)
  - This effort was reprogrammed to the DoD Chemical and Biological Defense Program in January 2001.

(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.
  - 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 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.

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- 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 common data set in-vivo qualifying systems for testing broad-spectrum anti-bacterial drugs.
  - Establish drug lead optimization program to facilitate transition process.

- 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 IND enabling studies.
  - Develop novel, bactericidal technologies for rapid post exposure treatment.

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- External Protection. ($ 8.180 Million)
  - Test a prototype air purification system for collective protection for a group of soldiers.
  - Demonstrate an individual water purification system 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.
  - 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.

- 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 hierarchial biochip sensors.
  - Extend standoff techniques for improved discrimination.
  - 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 TOF mass spectrometer counter-proliferation related work.

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- Complete first end-to-end performance characterization for complete sensor systems in real operational environments.
- Develop conceptual designs and critical technologies for novel warning systems, such as networked surveillance systems.
- Design and begin fabrication of universal probe biosensor suitable for forensics, biomedical surveillance, and environmental sensing.
- Evaluate universal probe biosensor against non-culturable organisms.
- Develop techniques for universal probes appropriate to viruses.
- Explore BW background spectral signatures and initiate standoff sensor development 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.

• 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.
  - Initiate systems design for building protection systems.
  - 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.
  - Develop critical technologies for novel protection systems, such as portal barriers.

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

	FY2000	FY 2001	FY 2002
Previous President's Budget	131.705	162.064	160.180
Current Budget	124.272	166.769	140.080

(U) Change Summary Explanation:

FY 2000	Decrease reflects SBIR reprogramming and minor program repricing.
FY 2001	Increase reflects net effect of congressional program reduction; congressional adds for DNA Chip Technology Research, Bio & Chem Terrorism Response Training Program, Asymmetrical Protocols for BWD, and Desalination Research; the Section 8086 reduction; and the government-wide rescission.
FY 2002	Decrease reflects end of Consequence Management and Genetic Sequencing efforts in FY 2001.

(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 Tactical Technology PE 0602702E , R-1 #18

COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	144.194	215.896	173.885	153.348	163.600	171.300	184.300	184.300	Continuing	Continuing
Naval Warfare Technology TT-03	13.499	4.965	15.000	15.000	20.000	26.200	36.200	36.200	Continuing	Continuing
Advanced Land Systems Technology TT-04	26.034	15.137	24.425	27.348	29.162	35.144	35.144	35.144	Continuing	Continuing
Advanced Tactical Technology TT-06	37.483	26.207	57.062	52.313	48.230	41.371	41.371	41.371	Continuing	Continuing
Aeronautics Technology TT-07	43.854	32.835	43.941	34.887	42.450	44.291	47.291	47.291	Continuing	Continuing
Advanced Logistics Technology TT-10	14.958	27.596	23.564	23.800	23.758	24.294	24.294	24.294	Continuing	Continuing
Joint Logistics ACTDs TT-11	8.366	9.856	9.893	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Unmanned Systems TT-12	0.000	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 includes congressionally added funding for Unmanned Systems initiatives (Project TT-12).

(U) The Naval Warfare Technology project is focusing on enabling technologies for a broad range of naval requirements. Programs include Friction Drag Reduction, High Energy Density Materials, and Submarine Payloads and Sensors. The Friction Drag Reduction program will develop friction drag reduction technologies for surface ships and submersibles. The High Energy Density Materials program explored high risk/high pay-

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off breakthroughs in missile propellants and explosives technologies. The Submarine Payloads and Sensors effort explored submersible platforms designed to maximize payload capacity. This project also includes 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 NetFires program (formerly Advanced Fire Support Systems) will provide rapid response and lethality associated with gun and missile artillery, thereby increasing survivability, yet requiring fewer personnel and less logistical support. 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 Low Cost Guided Medium Caliber Projectiles program will develop affordable guidance and control technologies for 25-60mm gun launched projectiles. The Counter-artillery Force Protection program explored advanced sensors, munitions and deployment concepts to counter evolving threats. The Dog's Nose/Unexploded Ordnance Detection program developed sensors for the chemically specific detection of explosives or other chemicals, comparable to the effectiveness of canine olfaction detection.

(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; new tactical systems for enhanced air vehicle survivability, advanced airbreathing weapons, enabling technologies for advanced space systems; emerging payload delivery concepts; and miniature air-launched decoy systems.

(U) The Aeronautics Technology project will explore 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 a new family of micro-air vehicles; micro adaptive flow control technologies; small-scale propulsion system concepts; innovative vertical take-off and landing concepts; ceramics for propulsion systems; quiet supersonic aircraft platforms; long endurance unmanned air vehicle concepts; and a hypersonic flight demonstration.

(U) The Advanced Logistics project is investigating and demonstrating 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 (ACTDs), will develop and migrate interoperable web-based joint logistics decision support tools (JDSTs) to the Service logistics communities.

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

(U) <u>Program Change Summary:</u> (*In Millions*)	**<u>FY2000</u>**	**<u>FY 2001</u>**	**<u>FY 2002</u>**
Previous President's Budget	142.501	121.051	126.679
Current Budget	144.194	215.896	173.885

(U) Change Summary Explanation:

FY 2000	Increase reflects minor reprogrammings.
FY 2001	Increase reflects net effect of congressional reductions for Advanced Rotorcraft Technology and Compact Lasers; congressional adds for the Unmanned Systems Initiative (Project TT-12) and the Center of Excellence for Research in Ocean Sciences (TT-03); the Section 8086 reduction; and the government-wide rescission.
FY 2002	Increases reflect continuation of the Naval Warfare project (TT-03) to develop Friction Drag Reduction technologies; increase in the Advanced Tactical Technology project (TT-06) for new solid state laser work; and increase in the Aeronautics Technology project (TT-07) for the Hypersonics program.

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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 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Naval Warfare Technology TT-03	13.499	4.965	15.000	15.000	20.000	26.200	36.200	36.200	Continuing	Continuing

(U) Mission Description:

(U) The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. The principal enabling technologies include investigation into High Energy Density Materials (HEDM) for advanced explosives and propellants and innovative payload and platform concepts for expanding the envelope of operational capabilities for surface and submersible platforms.

(U) The Friction Drag Reduction program, beginning in FY 2002, will further develop friction drag reduction technologies, investigated under PE 0601101E, Project MS-01 in FY 2000/2001, 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 High Energy Density Materials (HEDM) program fostered high-risk/high payoff efforts in missile propellant and explosives technologies applicable to a wide variety of tactical and strategic military systems. The HEDM project investigated the synthesis of new molecules capable of providing orders of magnitude increases in explosive and/or propulsive energy per unit weight. The potential benefits included: thermodynamic properties which could result in their having two-to-six times as much propulsive/explosive energy as current state-of-the-art operational materials, the "greening" of production and use, and reduction of detectability.

(U) The Submarine Payloads and Sensors Program explored the possibilities that emerge when a unified set of payload and sensor concepts, operational implications, and supporting platform concepts are formulated in a balanced manner. Technology and programmatic roadmaps for the interlocking payload, sensor, combat system and platform concepts that evolve were defined as part of this effort. Mature efforts identified for further development in FY 2001 and beyond are budgeted in Program Element 0603763E, Project MRN-02, Marine Technology. Core program transitioned to Navy in mid FY 2001.

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(U) The Center of Excellence for Research in Ocean Sciences (CEROS) objectives are to support 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 include shallow water surveillance technologies, ocean environmental preservation, new ocean platform and ship concepts, ocean measurement instrumentation, and unique properties of the deep ocean environment.

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

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

- High Energy Density Materials (HEDM). ($ 4.146 Million)
  - Initiated techniques to scale up synthesis of High Energy Density Materials (HEDM) to gram quantities and experimentally verified physical properties.
  - Conducted preliminary experiments related to synthesis of novel nitrogen molecules ($N_5^+ N_3^-$).
  - Explored other synthesis methods.

- Submarine Payloads and Sensors. ($ 2.353 Million)
  - Completed concept development phase, refined and finalized multiple payload and sensor concepts and associated mission concepts.
  - Defined and matured two flexible platform concepts capable of supporting multiple payload and sensor concepts.
  - Identified development roadmaps and technology risks and opportunities associated with the final system and platform concepts.

- Center of Excellence for Research in Ocean Sciences (CEROS). ($ 7.000 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.

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(U) FY 2001 Plans:

- CEROS. ($ 4.965 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.

(U) FY 2002 Plans:

- Friction Drag Reduction. ($ 15.000 Million)
  - Develop methodology for scaling drag reduction results previously demonstrated in Budget Activity 6.1 funded 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.
  - Calculate drag reduction in operationally relevant systems.
  - Commence optimization and engineering of polymer and/or microbubble properties in operationally relevant configurations.
  - Commence development of larger scale models.

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

Submarine Payloads and Sensors:

Source	FY 2000	FY 2001	FY 2002
Navy, PE 0603561N, Advanced Submarine Development	2.500	9.600	16.900

(U) Schedule Profile:

- Not Applicable.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Land Systems Technology TT-04	26.034	15.137	24.425	27.348	29.162	35.144	35.144	35.144	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: NetFires; Antipersonnel Landmines Alternatives; Close-In Sensing; Low Cost Guided Medium Caliber Projectiles; Dog's Nose/Unexploded Ordnance Detection and Counter-artillery Force Protection (CFP).

(U) The NetFires program (formerly Advanced Fire Support System) is developing and testing a containerized, platform-independent multi-mission weapon concept as a supporting element of the Future Combat System (FCS). NetFires will provide rapid response and lethality in packages requiring significantly fewer personnel, decreased logistical support, and lower life cycle costs, while increasing survivability compared to current gun and missile artillery. NetFires will allow FCS to defeat all known threats in a system compatible with air deployability in C-130 (and smaller) aircraft and enhance the situation awareness and survivability of FCS by providing extended-range, non-line-of-sight engagements. Beginning in FY 2001, NetFires is funded from PE 0603764E, Project LNW-03, Future Combat Systems.

(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 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

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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 Low Cost Guided Medium Caliber Projectiles program is focused on developing affordable guidance and control (G&C) technologies for 25-60mm gun launched projectiles. Today, missiles, rockets, some mortars, and some large caliber weapon systems have G&C components that make them precision munitions. Medium caliber guns are used primarily for line-of-sight engagements in situations where effectiveness is based on delivering high rates of fire, using a large number of rounds, to defeat a variety of targets from ground and air platforms. Potential advantages of low cost G&C systems for improving accuracy (i.e. probability of hit and probability of kill) of medium caliber gun launched projectiles include: 1) significantly reduced logistics burden associated with ammunition re-supply, 2) extended range and area of influence of medium caliber weapons, and 3) option of employing inexpensive medium caliber rounds to accomplish some missions that currently require expensive material (large caliber rounds and missiles.) The focus of this effort is on overcoming technical challenges associated with miniaturization of guidance and maneuver components, while keeping the cost per round low enough to be accepted as an affordable option. Primary program goals are to: 1) demonstrate an order of magnitude decrease in the number of rounds that must be fired to achieve the same effectiveness as current medium caliber systems, and 2) demonstrate significantly enhanced performance and effectiveness of medium guns against stationary and moving targets by enhancing accuracy and precision at range. Technical challenges include: 1) designing low cost, small guidance systems that can withstand very high G loading and projectile spin; 2) designing low cost, small, effective maneuver mechanisms to divert or correct course of the bullet in flight; and 3) devising inexpensive methods for testing and evaluating performance of smart bullets, since current test methods are destructive to the on-board components and gun ranges typically are not instrumented to record the bullet's behavior in flight.

(U) The Dog's Nose/Unexploded Ordnance (UXO) Detection program developed sensors for the chemically specific detection of explosives or other chemicals characteristic of land mines and/or shallowly buried UXOs. The sensors developed under this program provide soldiers with the effectiveness of canine olfaction detection without the logistics and other constraints imposed by the use of live animals. These chemically specific sensors can work either singly or in conjunction with other technologies such as the hyperspectral mine detector.

(U) The Counter-artillery Force Protection (CFP) program developed concepts for defending forces and civilian enclaves against air threats including high rate of fire missile artillery carrying submunitions. The program explored advanced sensors, munitions and deployment concepts to counter this evolving threat, including both active defense and counterforce options.

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(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- NetFires (formerly Advanced Fire Support System). ($ 12.074 Million) [Future Combat Systems – related = $12.074 Million]
  - Completed detailed design for an objective demonstration system, including launch, fire control, and each of the demonstration flight systems.
  - Tested component hardware and software.
  - Continued advanced concept feasibility assessments.
  - Initiated hardware-in-the-loop tests.
  - Awarded follow-on options for NetFires precision and loitering attack missiles, container launcher unit, and command and control modules.

- Counter-artillery Force Protection (CFP). ($ 1.006 Million)
  - In conjunction with the Army, defined system architectures, including sensors, munitions and deployment to meet the mission needs for enclave protection against missile artillery.

- Unexploded Ordnance Detection. ($ 5.982 Million)
  - Continued the development of chemical sniffers for land mine detection.
  - Reduced sized, improved field response to interferents, and improved sampling system.
  - Demonstrated a condensed phase detector in the field in multiple configurations (handheld and vehicle mounted) and formalized transition with the user.

- Antipersonnel Landmine Alternatives. ($ 6.972 Million)
  - Began preliminary development of antitank minefield healing algorithms.
  - Conducted initial experimentation of self-healing minefield subsystems – individual mine-surrogate mobility concepts and mine-to-mine communication methods.
  - Developed and demonstrated tagging concepts in the laboratory.

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

- Antipersonnel Landmine Alternatives. ($ 9.572 Million)
  - Conduct initial field experiments of self-healing minefield system.
  - Demonstrate autonomous location of individual mines and minefield mapping.
  - Evaluate tag communication range.

- Close-In Sensing. ($ 5.565 Million)
  - Investigate potentially promising radio frequency phenomenology collection techniques.
  - Investigate extremely lightweight, low cost active array technologies.
  - Explore multiple mission platform concepts.

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

- Antipersonnel Landmine Alternatives. ($ 8.281 Million)
  - Integrate final self-healing minefield system concept.
  - Build and test in field 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.

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- Low Cost Guided Medium Caliber Projectiles. ($ 7.773 Million)
  - Perform system analyses and studies to determine the increase in battlefield effectiveness possible with greatly improved accuracy for medium caliber bullets.
  - Determine which existing medium caliber weapons would serve as best first demonstrator and which missions would benefit most.
  - Conduct studies to identify several candidate technologies/approaches and to understand challenges, risks and scaling factors for each potential concept.

(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 Tactical Technology PE 0602702E, Project TT-06					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Tactical Technology TT-06	37.483	26.207	57.062	52.313	48.230	41.371	41.371	41.371	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 (10x 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 combining 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 3-dimensional imaging and targeting at very long ranges (> 1000 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 system 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 10x 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, 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 and processing for object identification in dispersive and turbulent media; and novel approaches to multiplexed hyperspectral chemical/biochemical sensing systems.

(U) The Rapid Access, Small Cargo, Affordable Launch (RASCAL) program will develop and demonstrate the capability to launch small (<110 lb) satellites and commodity payloads into low Earth orbit (LEO) on demand and for a total launch cost of $5,000 per pound or less. This

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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.

(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 either 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. It will convert the water to hydrogen and oxygen for use in thrusters. It will also 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. The Water Rocket program will develop technologies and demonstrate that the subsystems can be designed and built as space qualified. 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) The Precision Optics program developed mathematical design tools and fabrication strategies for conformal sensor windows, cylinders, toroids, and diffractive optical elements. These tools and strategies provide distortion-free imaging with greater than hemispherical field-of-regard and reduced aerodynamic drag for precision strike and integrated bomb damage assessment for next-generation airborne platforms/high-speed missiles.

(U) The Miniature Air-Launched Decoy (MALD) advanced concept technology demonstration (ACTD) program developed and demonstrated a small, inexpensive air-launched decoy system for Suppression of Enemy Air Defenses (SEAD). MALD will be employed to enhance the survivability of friendly aircraft by establishing air superiority through stimulating, diluting and confusing enemy Integrated Air Defense Systems (IADS). Other applications of the miniature air vehicle system will employ other electronic warfare approaches, which include coherent radio frequency (RF) spoofers, and RF jammers. The Air Force has budgeted procurement funding for this effort starting in FY 2001.

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(U) The Affordable Rapid Response Missile Demonstrator (ARRMD) pursued a high-speed air breathing propulsion system with more than triple the installed specific impulse (ISP) of current rocket power systems.

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

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

- Compact Lasers. ($ 12.037 Million)
  - Initiated development of system applications concept and preliminary design of spatial light modulators and integrated electronics for Coherent Communications, Imaging and Targeting (CCIT).
  - Performed feasibility studies and concept development of enabling alignment and docking technologies using compact solid-state laser technology.

- Precision Optics. ($ 6.111 Million)
  - Completed assembly and test of conformal optics Stinger missile dome to quantify performance improvements.
  - Demonstrated imagery through Stinger conformal missile dome.

- High Performance Algorithm Development. ($ 8.499 Million)
  - Demonstrated utility of multiscale segmentation and registration algorithms in DoD automatic target recognition applications.
  - Developed advanced mathematical algorithms for high throughput hyperspectral infrared imaging.
  - Validated fast algorithms for electromagnetic scattering at subwavelength scales and off of rough surfaces.
  - Developed codes for predicting antenna radiation patterns and scattering off of electrically large, smooth impenetrable bodies.

- Advanced Mathematics for Microstructural Process Control. ($ 2.197 Million)
  - Constructed and tested control/optimization codes for sputtering, evaporation and molecular beam epitaxy reactors.
  - Extended level set methodology to complex diffusion processes in thin film processing.

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- Miniature Air-Launched Decoy (MALD). ($ 0.535 Million)
  - Continued operational assessment exercises with thirty-two test assets to support transition to Air Force.
  - Continued to investigate ACTD design shortfalls and testing anomalies. Supported redesign efforts to increase reliability.
  - Coordinated transition of the MALD Program to the Air Force for initial quantity buy (150 units).

- Affordable Rapid Response Missile Demonstrator (ARRMD). ($ 5.738 Million)
  - Conducted booster configuration trade study.
  - Conducted second force and moment test series.
  - Performed design optimization studies.
  - Selected demonstration booster configuration.
  - Conducted structural validation testing.
  - Completed system preliminary design.
  - Continued exploration of supporting technologies for hypersonic missiles.

- Advanced Tactical Technology Concepts. ($ 2.366 Million)
  - Explored and assessed feasibility of new concepts for high-speed launch of small payloads and autonomous maintenance capabilities, exploiting next generation space-based sensors (e.g. lasers, electro optic, and millimeter wave).

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

- Compact Lasers for Coherent Communication, Imaging and Targeting. ($ 6.664 Million)
  - Continue development of system applications concept and preliminary design of spatial light modulators and integrated electronics for Coherent Communications, Imaging, and Targeting (CCIT).
  - Develop breadboard system with high-speed electronics integration.
  - Develop very high power short pulse lasers using plasma based pulse compression.

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- High Performance Algorithm Development. ($ 13.495 Million)
  - Demonstrate feasibility and portability of optimized portable application library generation approaches for a complete signal-processing algorithm.
  - Develop and test algorithms for variable precision filters for adaptive signal processing.
  - Develop tool set implementing algorithmic, memory, and compilation models applied to a multipole test problem.
  - Develop algorithms for predicting and optimizing antenna radiation patterns and scattering, both off of, and through, inhomogeneous materials and deep cavities.
  - Develop computationally efficient geometric compression and registration algorithms for topography/imagery databases.

- Advanced Mathematics for Microstructural Process Control. ($ 3.300 Million)
  - Validate reduced order model and algorithms for sensing and control of thin film vapor deposition processes.
  - Demonstrate advanced molecular dynamics/accelerated molecular dynamics simulation techniques for the growth of multilayer materials.

- Advanced Tactical Technology Concepts. ($ 2.748 Million)
  - Perform 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) **FY 2002 Plans:**

- Compact Lasers for Coherent Communication, Imaging and Targeting. ($ 7.785 Million)
  - Develop 32x32 unit cell scalable spatial light modulator with integrated electronics.
  - Develop breadboard system with application specific hologram processor, receiver, and short pulse amplifier.
  - Demonstrate greater than 1-kilometer operation for static platform and target.

- High Power Lasers. ($ 13.000 Million)
  - Develop large mode-field area (LMA) 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.

- Mission Specific Processing. ($ 10.000 Million)
  - Conduct simulation and benchmarking of initial custom design techniques.
  - Verify 10x improvement in GOPS watts per square centimeter operations per second for key Digital Signal Processor (DSP) functions.
  - Develop detailed system architecture of wideband adaptive radar/electronic intelligence (ELINT)/seeker receiver.
  - Begin development of a wideband adaptive radar receiver based on custom cell libraries and module generators.

- 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.
  - Demonstration of 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.
  - Develop reduced-order models and algorithms for sensing and control of biochemical materials growth process.

- 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 2-D conformal arrays, which exhibit the same or better beam patterns than conventional arrays and yet use only one-third of the transmit/receive modules.

- Rapid Access, Small Cargo, Affordable Launch (RASCAL). ($ 4.277 Million)
  - Demonstrate aircraft propulsion adaptation to first-stage mission requirements.
  - Design and demonstrate first-stage guidance software.

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  - Conduct system requirements review and conceptual design review of approach.

- Water Rocket. ($ 5.000 Million)
  - Perform critical technology demonstrations and analysis of the system design for the regenerative fuel cell and other developmental components of Water Rocket.

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

	FY 2000	FY 2001	FY 2002
Miniature Air-Launched Decoy (MALD), PE 0603750D, Advanced Concept Technology Demonstrations	2.000	3.000	0.000

(U) **Schedule Profile:**

- Not Applicable.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Aeronautics Technology TT-07	43.854	32.835	43.941	34.887	42.450	44.291	47.291	47.291	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-Air Vehicles (MAVs), which are at least an order of magnitude smaller (about 15 cm in any dimension) than currently available flying systems, have been demonstrated under this program. The next phase of the program will focus on the development of MAVs to accomplish unique military missions, particularly with regard to flight operations in restricted environments. Such mission areas include: small unit reconnaissance and surveillance, inspection of ships and floating vehicles, support of military operations in urban terrain, targeting and tagging high-value targets in denied areas, biological/chemical agent detection, and characterization of gases and/or explosives. The resulting capability should be beneficial in varied warfighting environments such as: ports and harbors, complex topologies, heavily forested areas/dense foliage, 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 program focused on the technologies and components required to enable flight at small scales, including flight control, power and propulsion, navigation and communications. The program will continue to build upon these and 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 upcoming efforts within the MAV program is to further develop and integrate MAV technologies into militarily useful and affordable systems suitable for mission applications.

(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.

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(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 g 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 (200g) 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 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 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. In FY 2001, this program is funded in the 6.3 based Advanced Aerospace Systems (PE 0603285E).

(U) DARPA, in partnership with the Office of Naval Research (ONR) and industry, formulated the Canard Rotor/Wing (CRW) program to explore an innovative vertical take-off and landing (VTOL) concept with the potential for significant performance improvements that would satisfy stressing mission needs. The CRW aircraft offers the potential for a high speed (350 knots), rapid response capability from a VTOL unmanned air vehicle with significant range (500 nm) and stealth improvements as compared to other VTOL concepts. Funding under this project will be used to complete fabrication and perform flight tests of this scaled vehicle concept in order to 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) The Hypersonics program 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 average speed above Mach 4, maximum sustainable cruise speed in excess of Mach 6, and the ability to dispense a simulated or surrogate submunition. Technical challenges

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include propulsion systems, hot primary and control surfaces, integral thermal/structural/fuel management, adaptive (possibly autonomous) guidance and control, conformal antennas/apertures, reliable health management and prognostics. An enabling element of hypersonic vehicles is the materials and structures necessary to meet these challenges. DARPA aims to develop lightweight, high temperature-capable and high reliability multifunctional (e.g. integral antennas and apertures; self diagnostic and self healing) material systems specifically optimized for hypersonic flight.

(U) DARPA is continuing its investment in innovative, long endurance UAV technology. The military application of such vehicles is the provision of reliable, tactically controlled ISR and communications equivalent to LEO 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) Ceramic components directly enable high performance propulsion systems and advanced air vehicles. Propulsion system performance is greatly improved by increasing combustion and turbine inlet temperatures. Current propulsion systems are temperature limited because of temperature fatigue limits of conventional metal alloy engine components, particularly in the turbine. Ceramic materials have superior high temperature performance compared to metals. Ceramics applied to key propulsion system components will enable higher temperature operation with an additional benefit of lower weight compared to conventional metal alloy systems. New engine paradigms will be developed that utilize the unique characteristics of ceramic materials.

(U) The goals of the Advanced Rotorcraft Technology (ART) program were to investigate the merits of various advanced rotorcraft technologies and to conduct technology maturation efforts for select high risk, high payoff technologies: face gear, split torque transmissions, and variable diameter tilt rotors.

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

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

- Micro Air Vehicle (MAV). ($ 7.393 Million)
  - Continued development of flight enabling technologies for MAVs.

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- Completed prototype fabrication, flight-testing and demonstration of multiple fixed-wing and rotary-wing vehicles.
- Completed development of MAV compatible power and propulsion subsystems, autonomous navigation and control subsystems using GPS for fixed wing MAVs, and video sensor subsystems.
- Continued concept of operations evaluation for military use and identified new mission opportunities.
- Completed development of basic enabling MAV technologies and subsystems.

• Micro Adaptive Flow Control (MAFC). ($ 8.498 Million)
  - Continued MAFC actuator and controller development. Assessed actuator and control system performance, control authority, bandwidth and power requirements.
  - Integrated open-loop MAFC technology into feasibility demonstrations for selected military applications, including high-work compressors, maneuvering of uninhabited air vehicles, and fixed-and rotary wing air vehicles.
  - Initiated systems studies for new applications 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 (STOVL) exhaust acoustic control.

• Small Scale Propulsion Systems (SSPS). ($ 4.465 Million)
  - Completed concept evaluation of several small-scale propulsion systems, including turbines, rockets and internal combustion designs.
  - Began detailed design of selected prototype propulsion systems.

• Advanced Aeronautic Concepts. ($ 3.030 Million)
  - Conducted technology assessments and feasibility testing of advanced aeronautic concepts, including supersonic laminar flow, air-to-air resupply and continuous aerodynamic control surfaces.

• Canard Rotor/Wing (CRW). ($ 1.588 Million)
  - Continued propulsion, aerodynamic and flight control risk reduction activities in conjunction with ongoing demonstrator fabrication for CRW concept.

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- Advanced Rotorcraft Technology (ART). ($ 3.880 Million)
  - Completed the mechanical reliability testing of the variable diameter tilt rotor sliding bearing under various environmental conditions including ice and exposure to sand as well as extreme hot and cold ambient temperature conditions.
  - Completed design and testing of an AH-64 sized face gear helicopter transmission.

- Quiet Supersonic Platform. ($ 15.000 Million)
  - Initiated 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.
  - Initiated development of highly integrated systems concepts for a supersonic long-range aircraft.

(U) FY 2001 Plans:

- Micro Air Vehicles. ($ 3.379 Million)
  - Continue enabling technology development, including power/propulsion, aerodynamics, guidance, navigation and control, and conduct system integration studies.
  - Perform IR Micro-sensor and collision avoidance sensor demonstrations.
  - Conduct MAV system lab demonstrations for new mission opportunities.

- Micro Adaptive Flow Control (MAFC). ($ 14.871 Million)
  - Initiate fully implemented MAFC technology development and validation tests for scale model of V-22 lift enhancement, high speed inlet mesoflaps, large scale wing model synthetic jet lift control, and delayed retreating blade stall.
  - Complete demonstration of high-speed compressor stage with aspiration flow control to give pressure rise of 3.4 across the stage.
  - Complete demonstration of biomorphic flapping flight.
  - Initiate the development of closed-loop MAFC technologies toward feasibility demonstrations.

- Small Scale Propulsion Systems (SSPS). ($ 10.401 Million)
  - Complete detailed design for propulsion systems.
  - Complete critical subsystem fabrication and testing.

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- Begin fabrication of full propulsion systems.

- Advanced Aeronautic Concepts. ($ 2.990 Million)
  - Continue 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.

- Canard Rotor/Wing (CRW). ($ 1.194 Million)
  - Complete demonstrator fabrication and conduct hardware in the loop and ground testing.

(U) FY 2002 Plans:

- Micro Air Vehicles (MAV). ($ 3.000 Million)
  - Continue enabling technology development and system integration studies.
  - Initiate designs of MAV systems for restricted maneuvering.
  - Conduct lab demonstration of geo-location and relative position location without GPS.
  - Perform MAV system mission demonstration.

- Micro Adaptive Flow Control (MAFC). ($ 8.014 Million)
  - Continue closed-loop MAFC actuator and controller development. 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.

- Small Scale Propulsion Systems (SSPS). ($ 7.627 Million)
  - Complete initial fabrication and testing of propulsion systems.
  - Complete vehicle integration studies.

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- Canard Rotor/Wing (CRW). ($ 0.800 Million)
  - Conduct demonstrator flight tests and produce final report.

- Ceramics for Propulsion Systems (CPS). ($ 4.500 Million)
  - Initiate technology development for advanced ceramic components.
  - Complete systems studies to determine payoff of monolithic ceramics and ceramic matrix composites in propulsion systems.

- Hypersonics. ($ 15.000 Million)
  - Evaluate concepts for lightweight, high temperature, multifunctional material systems.
  - Demonstrate thermal/structural load capability of candidate materials systems.
  - Conduct freejet engine testing.
  - Perform advanced combustion systems studies and fuel delivery system development.
  - Conduct vehicle system analysis and concept of operations studies.

- Long Endurance Hydrogen Powered Unmanned Air Vehicles. ($ 5.000 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) 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 Tactical Technology PE 0602702E, Project TT-10				
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Logistics Technology TT-10	14.958	27.596	23.564	23.800	23.758	24.294	24.294	24.294	Continuing	Continuing

(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) and the UltraLog Program.

(U) The Advanced Logistics Program (ALP) is investigating and demonstrating technologies that will make a fundamental difference in transportation and logistics. The program will define, develop and demonstrate 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. The ALP will leverage information technologies to address these shortcomings. In addition, the program has enormous potential for cost savings through greatly improved management of transportation and logistics assets. ALP will develop automated, multi-echelon, collaborative logistical/transportation technologies that will provide warfighters with an unprecedented capability to monitor, rapidly replan, and execute the revised logistics plan, as the situation requires, even while assets are enroute to the theater. The ALP is focusing 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 will 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 will be integrated to demonstrate a prototype end-to-end system solution.

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(U) The UltraLog program will build on the baseline security, robustness and scalability investigation and analysis initiated during the Advanced Logistics Program and 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 (IW) environments. Using the infrastructure developed by the Advanced Logistics Program, 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 (PKI) 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, ultra-efficient agent negotiations, 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, temporal horizons 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 2000 Accomplishments:

- Advanced Logistics Program (ALP). ($ 14.958 Million)
  - Developed capability to automatically plan and schedule movements from installation to the theater of operations and integrated the resulting movement plan with operations within the theater. Demonstrated capability for users to visualize multiple facts of the transportation schedule.
  - Developed capability to dynamically manage stockage levels across multiple supply chain levels and, multiple echelons, services and agencies.
  - Developed capability to automatically notify users when projected completion of an executing task differs from planned timeline.

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- Constructed and conducted a detailed baseline analytical evaluation of the ALP architecture for security, scalability and robustness.
- Established the development and experimental environments, which included the necessary security considerations and classifications for large-scale experimentation of agent societies under kinetic and information warfare environments.

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

- Advanced Logistics Program (ALP). ($ 9.855 Million)
  - Develop capability to automatically build and compare logistics plans in support of four operational courses of action in four hours.
  - Develop capability to monitor resource information, availability, capacity, costs and to view past, present and projected logistical situations.
  - Conduct a pilot test of advanced logistic technology using the Focused Logistics Wargame 2001.
  - Develop plans for conducting follow-on pilot tests.

- UltraLog. ($ 17.741 Million)
  - Establish the development and experimental environments and the metrics and methods by which the experimentation will be evaluated.
  - Design, develop and evaluate 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 the technical and functional requirements.
  - Perform systemic analysis of combinations and layering of developed technologies for overall effectiveness under varying experimental and environmental conditions.

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

- UltraLog. ($ 23.564 Million)
  - Develop, integrate and evaluate a synergistic collection of technologies providing dynamic information security, agent architecture survivability in an information warfare environment and sustained wartime logistics operations.
  - Establish instrumented and configurable wartime operating environment with chaotic real time systems, communications and event failures.

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- Conduct review by external, independent evaluation teams (red 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) **Other Program Funding Summary Cost:**

- Not Applicable.

(U) **Schedule Profile :**

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)						DATE June 2001				
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-11					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Joint Logistics ACTDs TT-11	8.366	9.856	9.893	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 (GCSS). The initial Joint Logistics ACTD addressed Commander-in-Chief (CINC) 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 awareness to the logistics commanders. JTL capabilities will include real-time interoperability between logistics and operations during all phases of planning and execution. Key data sources include 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 2000 Accomplishments:

- Joint Logistics ACTD. ($ 3.776 Million)
  - Expanded development of Joint Decision Support Tools (JDSTs) to depict both planned logistics unit support capabilities and actual capabilities.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-11	

- Successfully completed the final Military Utility Assessment that recommended JDST transition into Global Combat Support System (GCSS).
- Began to transition proven JDST capability through the Advanced Information Technology Services (AITS) Joint Program Office (JPO) into the Global Combat Support System.

• Joint Theater Logistics (JTL) ACTD. ($ 4.590 Million)
  - Began development of Joint Theater Logistics Decision Support Tools (JTLDSTs).
  - Started development of computer-assisted capabilities to evaluate operational and logistics tasks.
  - Initiated development of an operations/logistics collaboration capability using web-based visualization environment.
  - Began integration of fuel requirements and availability models into web-based collaboration.
  - Incorporated logistics support capabilities and operational concepts into a single integrated view.
  - Prepared to demonstrate JTL capabilities in a joint warfighting exercise.

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

• Joint Logistics ACTD. ($ 0.986 Million)
  - Transition Joint Decision Support Tools (JDST) capability into the Global Combat Support System.

• Joint Theater Logistics (JTL) ACTD. ($ 8.870 Million)
  - Expand 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. Track the execution of fuel sourcing, consumption, and sustainment.
  - Incorporate and enhance planned deviation detection technology and sentinels to compare planned resource requirements with near real-time operational logistic activity for select support items by location, provider, and intended consumer.
  - Develop capability to rapidly assess the impact of operational changes upon the logistics support structure. Develop a real-time in-theater management capability for critical resources including fuel and engineering support, which integrates execution of logistics support plans with logistics and operational data feeds.

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- Begin to develop the capability to forecast the impact of deviations and alternative support concepts upon future operations.
- Demonstrate multi-echelon collaboration of in-theater management capabilities in a joint warfighting exercise.

(U) **FY 2002 Plans:**

- Joint Theater Logistics (JTL) ACTD. ($ 9.893 Million)
  - Incorporate and enhance planned deviation detection technology and sentinels to compare planned resource requirements with near real-time operational logistic activity for select support items by location, provider, and intended consumer.
  - Provide the warfighter with near real-time operations and logistics collaborative capabilities to support planning and execution.
  - Incorporate technologies that will track planned versus actual movements and assess logistics 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 logistics overlays for the warfighter.
  - Demonstrate multi-echelon interoperability and in-theater management capabilities in a joint warfighting exercise.

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

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)						DATE June 2001				
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-12					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Unmanned Systems TT-12	0.000	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 project will pursue the development of unmanned advanced capability aircraft and ground combat vehicles consistent with Public Law 106-259 and 106-398. Systems to be developed under this project include Air Force and Navy Unmanned Combat Air Vehicles (UCAV) and Army Future Combat Systems (FCS). Funding for UCAVs in FY 2002 is contained in PE 0603285E, Advanced Aerospace Systems. Funding for Army FCS is budgeted in PE 0603764E, Project LNW-03.

(U) Funding in this project will accelerate risk reduction and "Concept of Operation" evaluation for the Unmanned Combat Air Vehicle program. Specific tasks include: (1) a full system level refinement of the current baseline UCAV Operating System design incorporating lessons learned from earlier Phase II efforts and recent AF operations, (2) additional constructive analysis to refine the existing mission effectiveness and affordability analysis, (3) design of the third demonstrator system (X-45B air vehicle, mission control system, and support segment) to a level equivalent to a critical design review for long lead items, and (4) design of the Block 3 system software build to demonstrated increased levels of adaptive autonomy by embedding the decision aid software, currently being designed into the mission control segment, into the on-board mission management system. Ultimately, this program will support the goal to demonstrate the technical feasibility for a UCAV system to effectively and affordably perform suppression of enemy air defenses (SEAD)/Strike missions in the post 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 21st century naval SEAD/Strike and 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, including: (1) demonstration of shipboard suitability; (2) demonstration of robust and secure command, control and communications; (3) exploration of the full range of man-in-the-loop controls and mission planning approaches; (4) evaluation of sensors, weapons load-out and mission effectiveness; and (5) demonstration of real time targeting and weapons delivery compatibility.

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APPROPRIATION/BUDGET ACTIVITY RDT&E Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-12

(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 Future Combat Systems (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 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 and simulation and experimentation to evaluate competitive concepts. The Future Combat System 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 (C4) functionalities; autonomous robotic systems; precision direct and indirect fires; airborne and ground organic sensor platforms; and precision, three-dimensional, air defense; non-lethal; adverse-weather reconnaissance, surveillance, targeting and acquisition (RSTA). The funds provided under this project will be used to accelerate the development of enabling technologies for unmanned systems within the FCS program. In addition, the funding under this project will be used to add an unmanned, remotely controlled aspect to the Future Combat Systems program.

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

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

- Not Applicable.

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

- Unmanned Combat Air Vehicle (UCAV). ($ 49.650 Million)
  - Design the X-45B system to a level equivalent to a critical design review for long lead items and develop the block 3 intelligent system software.

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- Naval Unmanned Combat Air Vehicle (UCAV-N). ($ 24.825 Million)
  - Acelerate conceptual designs of the naval unmanned operational systems and begin maturation of critical enabling technologies.

- Future Combat Systems (FCS). ($ 24.825 Million)
  - Conduct studies of unmanned ground vehicle resupply, air drop, cooperative behaviors, and artificial intelligence data processing.
  - Develop NetFires program boost test vehicles, seeker tower and captive flight tests and wind tunnel tests.
  - Develop low cost, low profile scanning K band antenna for the A160 hummingbird unmanned rotorcraft.
  - Mature technologies for communication relays between command and control elements and ground based fighting elements via unmanned airborne assets.
  - Develop 3-dimensional model-based environmental mapping capabilities using an active vision system incorporating a laser range finder and omni-directional camera.
  - Characterize the diversity of perception tasks that humans perform while driving vehicles for adaptation to robotic vehicle navigation.
  - Develop algorithms to differentiate vegetated from non-vegetated regions through innovative processing of the inputs from diverse sensors.
  - Utilize FOPEN radar and other sensors to conduct experiments to characterize terrain features including topography, biomass, cover and man-made objects.
  - Investigate C4ISR, command and control and employment issues for air and ground robots within the FCS force including the effectiveness of these robotic assests.

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

- Not Applicable.

(U) <u>Other Program Funding Summary Cost:</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 Unmanned Systems TT-12

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Integrated Command and Control Technology PE 0602708E, R-1 #19

COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	37.218	38.406	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Integrated Command and Control Technology IC-03	37.218	38.406	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) This program element is budgeted in the Applied Research Budget Activity because it develops the technologies for high definition displays that are important for virtually all DoD applications that involve visual and graphic information. Major components of this program include: projection, head mounted and direct view displays based on multiple technologies; development of equipment and components required to manufacture advanced display technologies; and prototyping of display systems for system evaluation. These efforts will establish a domestic technical capability for the manufacture of components necessary for military systems that capture, process, store, distribute and display high-resolution images. This project completes in FY 2001.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- High Definition Systems. ($ 18.891 Million)
  - Developed flexible, rugged displays based on organic electroluminescence and zero-power reflective technology.
  - Developed active matrix backplanes on flexible substrates for high performance/low power rugged displays.
  - Developed enhanced maturing technologies (organic electroluminescence, field emission and flexible field substrates) to performance capabilities required for DoD applications.
  - Demonstrated/inserted display technology into DoD systems to evaluate display technology.

- Flat Panel Displays. ($ 6.808 Million)
  - Continued Flat Panel Display manufacturing equipment and materials.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Integrated Command and Control Technology PE 0602708E

- Flexible Emissive Displays. ($ 11.519 Million)
  - Developed higher temperature plastic substrates compatible with display manufacturing.
  - Developed light emitting materials.
  - Demonstrated emissive monochrome display.

(U) **FY 2001 Plans:**

- Flexible Emissive Displays. ($ 15.888 Million)
  - Complete development of reduced water and oxygen substrate permeability.
  - Complete development of active matrix backplane transistors.

- High Definition Systems. ($ 15.567 Million)
  - Integrate organic light emitting diodes on flexible, active matrix backplanes for increased brightness and reduced power. Integrate Field Emission and Phosphor Display Technologies.
  - Complete evaluation of new display concepts for large, high-resolution displays.
  - Demonstrate/insert display technology into DoD systems for display evaluation.

- Flat Panel Displays. ($ 6.951 Million)
  - Complete Flat Panel Display manufacturing equipment and materials.

(U) **FY 2002 Plans:**

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Integrated Command and Control Technology PE 0602708E

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

	FY2000	FY 2001	FY 2002
Previous President's Budget	38.126	31.761	0.000
Current Budget	37.218	38.406	0.000

(U) **Change Summary Explanation:**

FY 2000 Decrease reflects minor repricing and SBIR reprogramming.
FY 2001 Increase reflects congressional add for Flat Panel Displays.

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

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001

APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, R-1 #20

COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	239.526	261.883	358.254	298.875	302.200	335.300	338.000	333.200	Continuing	Continuing
Materials Processing Technology MPT-01	129.488	147.455	175.531	145.017	136.985	169.744	172.444	173.684	Continuing	Continuing
Microelectronic Device Technologies MPT-02	83.248	92.550	92.229	59.858	70.215	80.556	85.556	85.556	Continuing	Continuing
Cryogenic Electronics MPT-06	26.790	21.878	9.994	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Beyond Silicon MPT-08	0.000	0.000	80.500	94.000	95.000	85.000	80.000	73.960	Continuing	Continuing

(U) Mission Description:

(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 (MPT-0l) concentrates on the development of novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components which 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, 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. This project also includes a biological systems

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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.). Electronics Textiles will develop new technologies and manufacturing techniques for economic manufacture of large-area, flexible conformable information systems

(U) The Microelectronics Device Technologies project (MPT-02) develops advanced electronic and optoelectronic devices, semiconductor process tools and methodologies, materials for optoelectronics and infrared devices. 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 includes a significant effort to develop advanced materials and device technology beyond the classical scaling limits of silicon device technology. A major initiative to explore the feasibility, design and development of information technology devices and systems utilizing non-silicon based materials and techniques has been initiated in FY 2001; these efforts transfer to project MPT-08 in FY 2002.

(U) The Cryogenic Electronics project (MPT-06) 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 (MPT-08) will investigate 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.

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

	FY2000	FY 2001	FY 2002
Previous President's Budget	242.267	249.812	230.267
Current Budget	239.526	261.883	358.254

(U) **Change Summary Explanation:**

FY 2000 Decrease reflects program repricings and SBIR reprogramming.

FY 2001 Increase reflects the net effect of congressional adds for 3-D Microelectronics; Strategic Materials Manufacturing; Materials in Sensors and Actuator Technology; partially offset by the Section 8086 reduction and the government-wide rescission.

FY 2002 Increase reflects expansion of the Materials Processing Technology project (MPT-01) for the following areas: electronic textiles, warfighter performance enhancements, risk reduction for new materials, and new approaches for water purification in the field and deriving power from the environment. The Microelectronic Device Technologies project (MPT-02) includes new initiatives for mixed signal microsystems and high frequency/high power wide band gap semiconductor electronics. The PE also reflects increased emphasis of the Beyond Silicon project (MPT-08), a planned follow-on to the FY 2001 project previously budgeted in MPT-02.

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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					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Materials Processing Technology MPT-01	129.488	147.455	175.531	145.017	136.985	169.744	172.444	173.684	Continuing	Continuing

(U) Mission Description:

(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. 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. Finally, engineered materials (metamaterials) are being developed that provide improvements in electromagnetic behavior across the complete array of defense applications.

(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. New techniques to determine structure and function of biomolecules and novel biomaterials to enhance the capabilities of the warfighter will be investigated..

(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.

(U) Finally, Electronics Textiles program will develop new technologies and manufacturing techniques for economic manufacture of large-area, flexible conformable information systems. This will be achieved through the combination of: textile science and manufacturing technology; novel materials (polymers, piezo and electrostrictive ceramics, shape memory alloys, fiber optics, etc); microsystems, architecture and algorithm technologies. A new community of electronic, computer, material, and textile scientists from industry universities and government will be formed to support this revolutionary new field.

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

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

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- Structural Materials and Devices. ($ 20.761 Million)
  - Integrated material concepts and materials systems into ultra-lightweight armor providing 100 percent improvement in personnel protection for the soldier.
  - Developed analytical, experimental, and simulation technologies for predicting the cost, performance, and life of advanced materials, decreasing the risk of and accelerating the time for insertion of new materials in Defense acquisitions.
  - Investigated concepts for the use of multifunctional materials in Defense applications (e.g., blast protection, thermal control) based on successes in ultra-lightweight metals and other structural materials programs.
  - Developed approaches for rapid design, optimization and assembly of small structures based upon solid freeform and rapid prototyping technologies.

- Mesoscopic Structures and Devices. ($ 9.487 Million)
  - Demonstrated the operation of a mesoscopic pump array with flow rates of several liters/min. in approximately one cubic inch.
  - Built and tested an individual integrated mesoscopic cooler.
  - Demonstrated a mesoscopic vacuum pump.
  - Demonstrated the ability to directly write active and passive electronic materials and components at the mesoscale.

- Smart Materials and Actuators. ($ 25.000 Million)
  - Demonstrated improvements in aerodynamic performance through wind tunnel testing of wings with adaptive leading and trailing edge control surfaces.
  - Developed a "smart skin" for the reduction of self-noise and radiated noise in torpedoes.
  - Explored novel actuator schemes for enhancing the performance of soldiers or devices.
  - Demonstrated techniques to grow large (>3 cm) single crystals of relaxor piezoelectrics.
  - Demonstrated the performance of single crystal piezoelectrics in broadband ultrasonic imaging transducers.

- Functional Materials and Devices. ($ 43.904 Million)
  - Demonstrated very fast (<20 nsec access time), high density, radiation hardened magnetic memory circuits utilizing both giant magneto-resistance (GMR) multilayers and spin dependent tunneling devices; established understanding of the micromagnetics of magnetic domain rotation in these devices.

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- Demonstrated very small, low power, high sensitivity magnetic gradiometers for the localization and identification of small ferrous objects.
- Demonstrated permanent magnet materials with 50 percent higher magnetic strength (energy product) and the ability to preserve magnetic properties to temperatures over 500?C.
- Demonstrated a loss tangent less than 0.002 in hybrid ferroelectric/ferrite (meta-material) devices.
- Demonstrated a broadband 360-degree phase shifter with very low loss for antenna feed applications.
- Demonstrated polymeric actuators that emulate the mechanical response and performance of human muscles.
- Demonstrated green light-emitting diodes (LEDs) fabricated from electroactive polymers with a half-life >5,000 hours; demonstrated blue and red LEDs with >1,000 hours half-life.
- Selected appropriate polymeric materials with electronic characteristics for field-effect transistor (FET) development.
- Demonstrated the growth of AlGaSb-InAs thin-films on GaAs substrates using the lateral epitaxial overgrowth technique.
- Demonstrated lattice mismatched epitaxial growth of dislocation free compound semiconductors using strain-absorbing layers.

• Bioinspired Materials and Devices. ($ 2.400 Million)
  - Explored sensormotory and navigational control schemes for biological systems through microelectronic interfaces.
  - Evaluated chemical, visual and acoustic cues used by biological systems for controlled locomotion, behavior and distribution.

• Advanced Energy Technologies. ($ 15.436 Million)
  - Demonstrated and field tested compact portable power systems in soldier applications.
  - Developed high efficiency direct thermal to electric energy conversion devices (in the laboratory).
  - Demonstrated (in the laboratory) power generation from the environment capable of operating unattended ground sensors.
  - Investigated novel concepts for small-scale, near ambient temperature, chemical power generation.

• Materials in Sensors. ($ 9.500 Million)
  - Continued work in materials and processing, including investigation of novel polymer and inorganic sensor and sensor protection schemes.

- Biodegradable Plastics. ($ 1.000 Million)
  - Initiated an effort to examine biodegradable plastics for Defense applications.

- Strategic Material Manufacturing. ($ 2.000 Million)
  - Continued the effort to develop new manufacturing approaches for cutting tools used for Defense strategic materials.

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

- Structural Materials and Devices. ($ 26.435 Million)
  - Demonstrate ultra-lightweight armor with 100 percent improvement over current materials and begin transition of manufacturing/design capabilities to the Army.
  - Demonstrate 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.
  - Continue the optimization of analytical, experimental and simulation technologies for determining the properties and processing of advanced polycrystalline, nanocrystalline and amorphous materials.
  - Select specific material(s) of high value to a DoD system for demonstration of accelerated insertion concepts.

- Mesoscopic Structures and Devices. ($ 14.200 Million)
  - Demonstrate initial, one-dimensional mesoscopic gyroscope operation that has drift rates <1.0?/hr.
  - Demonstrate fully functional integrated mesoscopic coolers that exhibit a coefficient of performance >3.
  - Demonstrate that direct-write mesoscale active and passive components have functionality close to discrete surface mount components.
  - Demonstrate the ability to direct-write mesoscale passive components (resistors, capacitors) and antennas on conformal surfaces.
  - Explore 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.

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  - Complete water tunnel test of a subscale submarine propulsor with active control to reduce acoustic radiation levels.
  - Explore techniques that use the intrinsic response of a material to its operating environment to provide diagnosis of the performance life of the material.
  - Develop approaches for integrating actuators, power systems and control methods to affect lightweight, energy efficient actuators for enhancing the performance of soldiers or devices.
  - Investigate artificial materials and membranes that can be integrated into controllable variable porosity fabric.
  - Demonstrate methods to fabricate multilayer actuators made from single crystals of relaxor piezoelectrics.
  - Demonstrate the performance of single crystal piezoelectrics in an advanced Navy sonar transducer.

- Functional Materials and Devices. ($ 41.212 Million)
  - Demonstrate a prototype, very high effective density (>16 Mbit), high speed (<10 nsec access time) magnetic memory circuit based on giant magneto-resistance (GMR) or spin-dependent tunneling utilizing very low power and low voltage (<2.5 volts).
  - Demonstrate a steerable, ferroelectric lens for phased array radar.
  - Demonstrate a conformal, frequency agile antenna that is 100 times cheaper than conventional technology.
  - Explore applications of meta-materials for advanced electromagnetic devices (e.g., antennas).
  - Demonstrate advantages of polymer-based actuators in specific Defense applications (e.g., robotics, sonar).
  - Demonstrate the use of electroactive polymers as thin-film spatial filters for quasi-real-time multispectral image analysis for enhancing target detectability.
  - Investigate 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. ($ 5.408 Million)
  - Identify candidates for advanced sensor systems that incorporate biologically inspired concepts including self-calibration, self-healing, variable temperature operation, functional responsiveness and mobility.
  - Construct prototype microelectronic interfaces for control of biological systems.

- Advanced Energy Technologies. ($ 16.900 Million)
  - Demonstrate energy harvesting from the environment for unattended sensor and soldier applications.

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- – Demonstrate (in the laboratory) high efficiency direct thermal to electric energy conversion operating on a liquid hydrocarbon fuel.
- – Develop specific approaches for small, chemical power generation that operates at near ambient temperatures.
- – Investigate novel ultra-high energy density power source concepts.

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

- Materials in Sensors. ($ 9.500 Million)
  - – Continue 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)
  - – Continue the effort 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)
  - – Full demonstration of ultra-lightweight armor materials in a system with 100 percent improvement over currently fielded systems and complete 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.

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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

- 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.
- 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. ($ 23.200 Million)
  - Demonstrate the ability to “dial-in” any passive component with at least 5 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. ($ 32.992 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 systems 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. ($ 43.030 Million)
  - 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 3D 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 (>1024).
  - Demonstrate 1.5 dimension acoustic imaging array technology with a large number of elements (>1024).
  - Develop mathematical methodology for predicting macroscopic material characteristics from unit cell properties.

• 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.
  - 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.
  - Explore multifunctional materials from organisms that survive environmental extremes and define design principles for biomimetic materials development.
  - Explore new methods for determining structure and function of bio-molecules.
  - Identify gene and gene related materials that are associated with stress reduction and extended performance.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-01

- 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 or thermionic 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. ($ 9.000 Million)
  - Design, fabricate and test 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.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)										DATE June 2001
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 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Microelectronic Device Technologies MPT-02	83.248	92.550	92.229	59.858	70.215	80.556	85.556	85.556	Continuing	Continuing

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

(U) This project develops advanced electronic and optoelectronic devices, semiconductor process tools and methodologies, materials for optoelectronics, and infrared devices. Areas of emphasis include high performance Analog-to-Digital (A/D) converters, military optical processors, novel integrated optoelectronic devices and components, photonics technologies, high temperature electronic devices, and high power electronics. In addition, this project develops and demonstrates advanced microelectronics technology for DoD critical needs including digital radar receivers and acoustic-electronic components. Technologies developed in this project are performance driven and exceed commercial capabilities.

(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 a new project, MPT-08, within this program element in FY 2002 and beyond.

(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 MEM switches, photonic band gap ground planes, high-density multi-layer interconnects, and fragmented antennas. These will be integrated into applications demonstrations that will show substantial new capabilities. These capabilities include multi-beam arrays for satellite-based communication links, which geometrically reconfigure to provide hemispherical coverage. Applications such as Future Combat System need such battlefield links. Techniques being developed will also allow soldier communication with wearable antennas and have application to Personal Communications System (PCS) in the commercial market. 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.

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(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. 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. 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 new initiatives starting in FY 2002 – 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 1000 through the introduction of analog optical signal processing components into the system front ends.

(U) Technology for Efficient, Agile Mixed Signal Microsystems (TEAM) is the 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 1 part per billion in 1 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) <u>Program Accomplishments and Plans:</u>

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

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- Reconfigurable Aperture (RECAP). ($ 8.327 Million)
  - Completed technology investigation, preliminary design and limited bread boarding of wideband antenna components.
  - Distributed Picasso modeling beta code to RECAP contractors to initiate user interaction and obtain requirements for next version.
  - Analyzed, modeled, and measured key technologies such as MEM switches, multi-layer substrates and configurable radiators.
  - Completed trade-offs of radiating elements and ground plane configurations.
  - Used genetic algorithms to develop a fragmented ground plane to meet 8:1 decade bandwidth requirements.
  - Completed Ultra thin lightweight designs of low frequency artificial magnetic conductors and progressed in material testing.

- Digital Receiver Technology. ($ 3.887 Million)
  - Demonstrated a very high performance analog-to-digital (A/D) converter with 14 effective bits, 60 MHz instantaneous bandwidth, and >86 dB spurious free dynamic range (SFDR) with potential for multiple military applications.

- High Powered Solid State Electronics. ($ 2.934 Million)
  - Demonstrated high-current density (>100 A/cm^2) 2500-V class switch from silicon carbide (SiC); demonstrated 2500-V rectifier diode from gallium-nitride (GaN).

- Sonoelectronics. ($ 6.561 Million)
  - Completed sonoelectronic camera prototype fabrication; carried out laboratory characterization and test-tank evaluation.
  - Demonstrated the lab-proven imager in a very-shallow-water (VSW) field setting.

- Acoustic Micro-Sensors. ($ 2.555 Million)
  - Initiated air-coupled acoustic micro sensor project to demonstrate chip-scale sensor system capable to locate, track and identify a sound source or a voice in a noisy environment.

- HERETIC. ($ 9.438 Million)
  - Completed integration of Heterostructure Integrated Thermoelectronic (HIT) device arrays with bias and control circuitry on GaAs substrates; completed integration of micro-jet, micro-nozzle or micro-thermionic arrays with bias and control circuitry over Si substrates.

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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

- Advanced Microelectronics (AME). ($ 9.444 Million)
  - Demonstrated circuit and modeling of a full-scale system (e.g. image processing system) featuring terascaled-compatible devices and associate technology far beyond the existing industry roadmap.

- VLSI Photonics. ($ 18.545 Million)
  - Developed VLSI heterogeneous integration technology and integrate micro-opto-mechanical components with VLSI chips; developed system-level CAD tools.

- Materials Integration on Silicon. ($ 10.875 Million)
  - Initiated an integration program that develops a tool kit of materials and processes for integration of multiple materials onto a single silicon substrate.

- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($ 8.682 Million)
  - Initiated program to begin a major development in photonics, using both wavelengths – wavelength optics – as well as spatial attributes of light – bulk optics.

- 3-D Microelectronics. ($ 2.000 Million)
  - Continued development of key technologies behind a packaging concept using a stacked MCM approach to reduce interconnect length and increase physical connectivity between layers of electronics.

(U) **FY 2001 Plans:**

- Reconfigurable Aperture (RECAP). ($ 14.246 Million)
  - Demonstrate fabrication and reconfigurability of fragmented antennas for wideband communication.
  - Construct wearable antennas with zero phase ground planes, switchable elements, and polyimide materials for low cost component fabrication.

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- Continue successful core technologies and initiate efforts for integrated system application demonstrations concentrating on battlefield communications through low profile satellite communications and wearable low frequency communication antennas, and space/air/surface/submarine-based electronic intelligence (ELINT), signal intelligence (SIGINT) and radar systems.
- Validate RENOIR modeling and simulation tool with experimental data.
- Demonstrate dual polarization conformal wideband antenna technology.

• Acoustic Micro-Sensors. ($ 5.911 Million)
  - Demonstrate MEMs-based 3-D acoustic transducers and/or transducer arrays with superior sensitivity, signal-to-noise ratio, and bandwidth that are current state-of-the-practice.

• HERETIC. ($ 7.884 Million)
  - Demonstrate HIT devices on GaAs having better specific heat-removal capacity as the best commercial-off-the-shelf TE coolers; demonstrate 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)
  - 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.

• VLSI Photonics. ($ 7.859 Million)
  - Demonstrate Synthetic Aperture Radar (SAR) processor using VLSI Photonics technologies; showcase reconfigurable cross-connect switching. Demonstrate rapid parallel access to memory using optical interconnection.

• Materials Integration on Silicon. ($ 8.959 Million)
  - Continue integration of new material and processes into a single silicon substrate that will drive system performance.
  - Demonstrate logic circuits and power amplifiers on silicon substrates.

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- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($ 10.843 Million)
  - Continue component development, integration, algorithms, architectures and sub-system functionality demonstrations.
  - Demonstrate emitters and detectors in the spectral band 350-500 nm.

- Beyond Silicon - Antimonide Based Compound Semiconductors (ABCS). ($ 7.944 Million)
  - Demonstrate non-silicon based transistors technologies based on low band gap materials capable of multi-gigahertz operation at bias voltages < 1 volt.
  - Demonstrate nanostructured materials for quantum based electronic and optoelectronic device applications.
  - Demonstrate a three terminal resonant tunneling device operating at several hundred GHz.

- Beyond Silicon - Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD). ($ 3.974 Million)
  - Develop fast algorithms for non-linear analysis of mixed signal systems – analog and photonic devices.
  - Extend algorithm methods to non-linear problems.

- Beyond Silicon - Polymorphous Computing Architecture (PCA). ($ 7.944 Million)
  - Initiate Polymorphous Computing Architecture (PCA) research efforts.
  - Identify and select DoD reactive in-mission and multi-mission applications of interest.
  - Develop PCA hardware abstraction models and stable architecture interfaces.
  - Identify multi-dimensional reactive computing, communication, memory, verification and optimization techniques.

- Beyond Silicon - Quantum Information Science and Technology (QuIST). ($ 15.000 Million)
  - Investigate techniques for building reliable scaleable quantum bits out of devices potentially subject to failures and decoherence, via efficient fault tolerant mechanisms.
  - Initiate investigation of new problem classes, beyond factorization and unsorted search, which are solvable with dramatic efficiency on a quantum computer.
  - Initiate theory and algorithm research for secure quantum communication; investigate techniques amenable for implementation in existing networks and fiber optic backbone.

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(U) **FY 2002 Plans:**

- Acoustic Micro-Sensors. ($ 4.753 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. ($ 7.604 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.

- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($ 11.406 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). ($ 8.120 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 with application to low band and satellite communications, ELINT/SIGINT, and radar.
  - Validated modeling and simulation software will be completed.

- Analog Optical Signal Processing (AOSP). ($ 8.346 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.

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- Test signal processing techniques of analog signals.
- Evaluate signal-processing algorithms.
- Evaluate photonic component performance requirements.

• Technology for Efficient Agile Mixed Signal Microsystems (TEAM). ($ 6.000 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 CMOS compatible fabrication processes that can yield integration levels > 10,000 nanoscale devices.

• Chip Scale Atomic Clock. ($ 5.000 Million)
- Demonstrate feasibility and theoretical limits of miniaturization of cesium clock.

• High Frequency Wide Band Gap Semiconductor Electronics Technology. ($ 11.000 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. ($30.000 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.
- Develop electro thermal models for analyzing high power, high frequency enclosures.
- 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.
- Develop thermal management concept for high power, high temperature devices.

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(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 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Cryogenic Electronics MPT-06	26.790	21.878	9.994	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. The project concludes in FY 2002.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Cryogenic Technologies. ($ 22.463 Million)
  - Developed devices and components, based upon superconducting and other electromagnetic materials that in a cryogenic environment would provide a 5-10 times-range improvement over conventional means for detection of low-level signals.
  - Completed adaptation of cryocoolers in microelectronics packages for communications transceivers.
  - Expanded efforts in mixed-mode electronics technology development to include tunable high temperature superconducting filters that preserve high-Q, with 10 percent tunability.

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- Thermoelectric Materials and Devices. ($ 4.327 Million)
  - Demonstrated thermoelectric cooling materials that can achieve 100°C cooling in two stages or less.
  - Demonstrated a thermoelectric converter with a factor of two improvement in power generation per unit size.

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

- Totally Agile Sensor Systems (TASS). ($ 21.878 Million)
  - Fabricate 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.
  - Design a complete cryogenic receiver module, incorporating tunable high temperature superconducting (HTS) antenna/pre-selector and digital microelectronics (with HTS embedded passives), displaying unsurpassed sensitivity and interference rejection.

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

- Totally Agile Sensor Systems (TASS). ($ 9.994 Million)
  - Incorporate agile front-end pre-selector modules on aircraft and ships, utilizing tunable high-Q HTS filters.
  - Demonstrate totally agile sensor systems with 10X SIGINT and COMINT capability.
  - Fabricate Thermoelectric (TE) modules that can be integrated with receiver front ends to provide cooling and/or thermal management as required for enhanced performance.

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

- Not Applicable.

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

- Not Applicable.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Beyond Silicon MPT-08	0.000	0.000	80.500	94.000	95.000	85.000	80.000	73.960	Continuing	Continuing

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

(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 will explore 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 will investigate 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. Research will include the formulation of new algorithms and protocols for ultra-secure communications, ultra-precise metrology, information-bandwidth enhancements, the limits of quantum computation for speedups over classical computation, and computational applications for which quantum computation offers significant advantage over known classical equivalents. Concurrently with these theoretical advances, QuIST will develop the component technology for secure quantum

* Funding for Beyond Silicon programs funded in PE 0601101E and PE 0602712E in FY 2001 totaled: $44.2 million.

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communication and quantum computation including the development of robust megahertz rate single photon sources and detectors, practical implementations of single and multiple quantum bit logic gates, quantum memory, and systems level constructs such as quantum repeaters. Theoretical and hardware developments will be integrated into demonstrations that may include scalable assemblies of quantum logic and memory, quantum teleportation-based communication, coherent optic quantum communication, ultra-precise clock synchronization and ultra-secure communication over large distances (100 km).

(U) The Polymorphous Computing Architectures program will develop 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. 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 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.

(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 >10% 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 and expands research in molecular electronics (Moletronics) 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 density. This research will also demonstrate the 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 the molecular circuits.

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(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Not Applicable.

(U) FY 2001 Plans:

- Initial funding for the following Beyond Silicon programs is contained in this PE under Project MPT-02:
  - Quantum Information Science and Technology. ($ 15.000 Million)
  - Polymorphous Computing Architectures. ($ 7.944 Million)
  - Antimonide Based Compound Semiconductors. ($ 7.944 Million)
  - Integrated Mixed Signal (A/D) and Electronic/Photonic Systems. ($ 3.974 Million)

- Initial funding for Moletronics is contained in PE 0601101E, Project MS-01. ($ 9.300 Million)

(U) FY 2002 Plans:

- Quantum Information Science and Technology (QuIST). ($ 22.500 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.
  - Demonstrate robust single photon sources and detectors.
  - 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. ($ 15.000 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.
  - Implement early prototyping of reactive concepts, software services.

- Antimonide Based Compound Semiconductors (ABCS). ($ 12.000 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). ($ 12.000 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.

- Moletronics. ($ 19.000 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.
  - Quantify the defect-tolerance required for a molecular-based computer to still function.

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

- Not Applicable.

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

- Not Applicable.

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COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	19.187	37.474	153.700	64.000	86.000	89.000	94.000	94.000	Continuing	Continuing
Advanced Aerospace Systems ASP-01	19.187	37.474	153.700	64.000	86.000	89.000	94.000	94.000	Continuing	Continuing

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

(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 or 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 Supersonic Miniature Air-Launched Interceptor (MALI) program will demonstrate 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. As a further cost reduction, the program will leverage off the existing 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 will be incorporated into the MALI core program due to the required data transmit/receive survivability configuration of the interceptor mission.

(U) The Navy and the Marine Corps have a need for affordable, survivable, vertical take-off and landing (VTOL) unmanned air vehicles (UAV) to support dispersed units in littoral and urban areas. DARPA, in partnership with the Office of Naval Research (ONR) and industry, has formulated the Advanced Air Vehicle (AAV) program to explore two innovative vertical take-off and landing (VTOL) concepts with the potential for significant performance improvements that would satisfy stressing mission needs. The first, an advanced Canard Rotor/Wing (CRW) aircraft, 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. The second concept (A160), will exploit a hingeless, rigid, rotor concept to produce a VTOL unmanned air vehicle

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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 UAV range (>2000nm) and endurance (>24-48 hours). Detailed design, fabrication and testing of this concept will be conducted to establish its reliability, maintainability and performance. Both the CRW and A160 are being explored 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.

(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. 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 2004, 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. (The FY 2001 funding of this program's technology development is exploiting the development of advanced tactical technology concepts and compact laser technologies (approximately $5 million) funded under PE 0602702E, Project TT-06 in FY 2000 as well as other efforts in this Project, ASP-01.)

(U) Within the joint DARPA/Air Force UCAV program, this project will continue risk reduction and "Concept of Operation" evaluation for the Unmanned Combat Air Vehicle. This project will complete the design of the system B demonstrator (X-45B Low Observability (LO) air vehicle, mission control system (MCS), and support segment) and begin development of its tailored sensor and communications suite. 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 SEAD/Strike missions in the 2010 timeframe. The FY 2002 program reflects continuation of an expanded and accelerated UCAV program that was initiated by the Congress through a major funding increase in FY 2001 (budgeted in PE 0602702E, project TT-12).

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(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 but will also stress maximum commonality with the Air Force UCAV.

(U) 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 (LCC) combat effective design for a multi-mission Strike, 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) Hybrid Cycle and Rocket program will develop and demonstrate the suitability of hybrid cycle propulsion, like airbreathing and rocket hybrid engines, and liquid and solid hybrid rocket motors, for high-performance tactical missiles and cost effective space access. Recent advances have made this technology viable for wider use in missiles and space booster applications. This program seeks to demonstrate hybrid technologies at the scales appropriate for tactical missiles, sounding rockets and stages for small launch vehicles. For space launch applications, this program also seeks to demonstrate hybrid technologies that have levels of reusability. During Phase I (Concept Definition) mission utility studies will be performed to focus the planned demonstrations towards viable applications. In this early phase, hybrid technologies will be demonstrated at the scale required for the final demonstrations. Critical reusability technologies will be demonstrated. During Phase II (Detailed Design and Subsystem Demonstration) detailed design of the entire booster and demonstration vehicle will be completed and ground tested. Phase III (Flight Demonstrations) will fly small-scale rocket boosters with reusable hybrid engines.

(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 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

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natural laminar flow, aircraft shaping, plasma, heat and particle injection, and low weight structures. In FY 2000, this program was funded in PE 0602702E, Project TT-07.

(U) Both the U.S. military and the U.S. 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 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 Space Object Identification System (SOIS). The SPAWN, SBMC^3, and SOIS programs are closely coordinated with the US Air Force and USCINCSPACE, and with DARPA's Advanced Space Surveillance Telescope (project SGT-02), Orbital Express (project ASP-01), and classified programs.

(U) The Satellite Protection and Warning (SPAWN) program will examine the impact of emerging micro and nano satellite threats (both offensive and defensive) to critical U.S. space assets, develop technologies, and devise techniques to counter these threats taking advantage of a satellite-servicing infrastructure. Potential solutions include delivery of expendable modules for satellite self-defense, ride along sensor packages and micro satellites that use a servicing spacecraft as a mother ship. A secondary goal is to explore novel methods and sensors to distinguish natural space phenomena from manmade attack. In Phase I the satellite warning and protection functions that will be emulated in the on-orbit demonstration will be examined, including detection, inspection and characterization of potentially hostile payloads, assessment of friendly payloads, and detection of electromagnetic surveillance. A preliminary system design will detail the number, types and configurations of sensors as well as the software required for target detection and assessment from which a warning condition will initiate an autonomous protection sequence. In Phase II, detailed design 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. During the first 4-6 months on-orbit, the Orbital Express experiment will repeatedly demonstrate the feasibility of autonomously upgrading, refueling and reconfiguring satellites. SPAWN will view these dockings on a non-interfering basis. Following the demonstration period, SPAWN will conduct proximity operations including detection, tracking, target inspection, and electromagnetic surveillance detection.

(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 control assets. SBMC^3 will provide algorithms that enable fusion and handoff of data between space sensors of widely different sensing modalities, locations, and reporting intervals. Protocols for information exchange

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within the space control architecture will be optimized. Information systems for highly automated space object tracking, identification, and activity assessment and spacecraft control will be developed. The space control 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 vehicles being controlled and objects being tracked, while maintaining assured human control of space activities.

(U) The Space Object Identification System (SOIS) program will develop sensing options for the imaging and characterization of 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. Technologies under consideration will include ground-based ladar and coherent radar, as well as space-based optical, infrared, and ladar sensors. The program will investigate novel focal plane array materials for the passive imaging of cold, faint objects and novel signal processing algorithms for non-imaging characterization. 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.

(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 10 times lower system noise and significant reductions in size and weight that scale with the overall size of the system.

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

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

- Advanced Air Vehicle (AAV). ($ 10.175 Million) [Future Combat Systems – related = $5.000 Million]
  - Completed preliminary and detailed design; began fabrication of two CRW demonstrators.

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

- Conducted tests of A160 air vehicle flight control system and rotor assembly.
- Continued fabrication of two A160 prototypes.

• Supersonic Miniature Air-Launched Interceptor (MALI). ($ 3.991 Million)
- Conducted Critical Design Review to establish vehicle configuration.
- Initiated engine and infrared (IR) payload testing.
- Initiated fabrication, assembly and risk reduction testing of air vehicle.
- Developed airborne inter-vehicle communications, mission processing and execution capability.
- Initiated test planning for flight demonstration of interceptor and collaborative formation mission.
- Explored other concepts for low cost MALI airframes to fill mission areas such as reconnaissance, surveillance, nuclear/biological/chemical (NBC) detection and jamming.

• Orbital Express Space Operations Architecture. ($ 5.021 Million)
- Initiated Phase I to identify, define and analyze the requirements for on-orbit satellite servicing.
- Began to analyze the utility, cost effectiveness and life-cycle costs.
- Started the Operational System Concept (OSC) redefinition.
- Began nomination process of a baseline satellite-servicing mission.
- Initiated the concept of operations (CONOPS) for servicing.

(U) **FY 2001 Plans:**

• Advanced Air Vehicle: Hummingbird Warrior. ($ 2.979 Million)
- Initiate flight tests of A160 air vehicle.
- Design sensor integration modifications to A160 air vehicle.
- Design low-vibration rotor modifications for A160.

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- Design unmanned ground vehicle (UGV) deployment system for A160.
- Study A160 scaling and signature reduction.

- Supersonic Miniature Air-Launched Interceptor (MALI). ($ 7.810 Million)
  - Complete air vehicle fabrication, assembly and conduct ground testing.
  - Complete engine and infrared (IR) payload testing.
  - Demonstrate inter-vehicle communications, mission processing and execution capability.
  - Perform supersonic engine flight verification and seeker/advanced payload verification.
  - Conduct flight demonstration of subsonic vehicle interceptor and collaborative formation flying mission.
  - Conduct free flight intercept demonstration against a representative target.
  - Continue to explore alternative mission concepts for low cost MALI airframes, including ground-launched variant of interceptor vehicle for use by land forces.

- Orbital Express Space Operations Architecture. ($ 6.825 Million)
  - Continue the identification, definition and analysis of the requirements for on-orbit satellite servicing.
  - Continue to analyze the utility, cost effectiveness and life-cycle costs.
  - Continue redefinition of the Operational System Concept (OSC).
  - Continue nomination process of a baseline satellite-servicing mission.
  - Continue to define a servicing concept of operations (CONOPS).
  - Define a draft, non-proprietary satellite-to-satellite interface standard.
  - Perform risk reduction research and development activities of critical items.
  - Complete initial demonstration test plan.
  - Conduct preliminary design review and develop Request for Proposals in preparation for Phase II.

- Quiet Supersonic Platform. ($ 19.860 Million)
  - Continue 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.

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– Develop conceptual designs for highly integrated supersonic long-range aircraft.

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

- Advanced Air Vehicle: Hummingbird Warrior. ($ 9.000 Million)
  – Fabricate and test low vibration rotor modifications for A160 air vehicle.
  – Integrate/demonstrate electro-optic/infrared (EO/IR) surveillance payload on A160 vehicle.
  – Integrate/demonstrate unmanned ground vehicle (UGV) deployment system on A160 vehicle.

- Supersonic Miniature Air-Launched Interceptor (MALI). ($ 3.000 Million)
  – Complete supersonic vehicle testing, final report and transition

- Orbital Express Space Operations Architecture. ($ 35.700 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.
  – Develop key enabling technologies and continue risk reduction activities.
  – Initiate fabrication of demonstration system/subsystems.
  – Initiate Auto Guidance, Navigation and Control (GN&C) system and software design.

- Unmanned Combat Air Vehicle (UCAV). ($ 60.000 Million)
  – Complete design and development of a third air vehicle (X-45B), which incorporates integrated apertures and antennas, integrated weapons, distributed avionic, Low-Observability (LO) treatments and exhaust, and increased functionality.
  – Conduct high-fidelity component radar cross-section (RCS) testing.
  – Initiate development of an advanced electronic support measures (ESM) subsystem, synthetic aperature radar (SAR), and satellite communication terminal tailored for the X-45B.

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- Complete design of a fully C2 interoperable mission control system (MCS) incorporating multilevel security features in both hardware and software.
- Complete design and begin development of the X-45B container and support equipment.

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

• Hybrid Cycle and Rocket Engines. ($ 4.000 Million)
  - Perform conceptual design, trade-studies and mission utility analysis.
  - Conduct initial technology and reusable technology demonstrations.

• Satellite Protection and Warning (SPAWN). ($ 4.000 Million)
  - Identify potential satellite threats and threat employment scenarios.
  - Define requirements for a nano-micro (10-100 kg) satellite for protection of on-orbit assets and threat characterization.
  - Identify candidate sensor technologies and characterization techniques, select approaches for further development.
  - Devise architectures and CONOPS; determine the feasibility and utility of these missions.

• Space Battle Management Command, Control and Communications (SBMC3). (4.000 Million)
  - Define computing and communication interfaces with legacy systems.
  - Devise computing and communication architectures and CONOPS; 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 computing communications algorithms and technologies.

• Space Object Identification System (SOIS). ($ 4.000 Million)
  - Perform analysis of on-orbit imaging requirements.

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- Identify candidate ground- and space-based sensor technologies.
- Identify candidate satellite characterization algorithms.
- Analyze predicted performance of candidate technologies and select approaches for further development.

• Space Technologies. ($ 3.000 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 RF, microwave and optical system.

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

	FY 2000	FY 2001	FY 2002
Previous President's Budget	17.071	26.821	32.700
Current Budget	19.187	37.474	153.700

(U) **Change Summary Explanation:**

FY 2000 Increase reflects minor program repricing.

FY 2001 Increase reflects net effect of congressional program reductions, congressional add for Supersonic Noise Mitigation, the Section 8086 reduction and the government-wide rescission.

FY 2002 Increase reflects a major expansion of the DARPA/Air Force UCAV program that continues program acceleration initiated by the Congress in FY 2001, rephasing of the Orbital Express Space Operations Architecture effort, expansion of A160 air vehicle technology development, the addition of the Hybrid Rocket program, and transition of Naval UCAV program from a study effort to a full program.

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

	FY 2000	FY 2001	FY 2002
• Unmanned Combat Air Vehicle (UCAV):			
Air Force	*	24.800	21.100
• Naval Unmanned Combat Air Vehicle (UCAV-N):			
Navy	1.500	1.500	15.000

*Classified

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

Plan	Milestones
Miniature Air-Launched Interceptor (MALI):	
Jul 01	Complete avionics environment verification testing.
Aug 01	Deliver first supersonic engine.
Aug 01	Conduct flight readiness review.
Sep 01	Captive carry flight test.
Oct 01	Perform intercept flight demonstration.
Dec 01	Complete supersonic flight demonstrations.
Advanced Air Vehicle (AAV):	
Aug 01	Design review for low-vibration rotor modifications and unmanned ground vehicle deployment system for A160.
Mar 02	A160 Electro-Optic/Infrared (EO/IR) payload first flight.
Jun 02	A160 Unmanned ground vehicle deployment system first flight.
Sep 02	A160 low vibration rotor first flight.
Jun 03	A160 Compound Helo Design Review.
Sep 03	A160 Flight with Forward Pass Ground Control Station.

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Orbital Express Space Operations Architecture:

Jun 01	Complete operational system concept, supporting trade studies, and satellite servicing CONOPS.
Sep 01	Conduct demonstration system preliminary design review. Complete demonstration system detailed test plan.
Jan 02	Select Phase II contractor team.
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.
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 (GN&C) software; begin testing in full motion simulation facility.
Sep 03	Begin payload integration testing into ASTRO and NextSat buses.

Unmanned Combat Air Vehicle (UCAV):

Aug 01	System B Interim Design Review.
Jan 02	System B mid-term Design Review.
Aug 02	System B Final Design Review.

Naval Unmanned Combat Air Vehicle (UCAV-N):

Nov 01	Pegasus first flight complete.
Apr 02	Conduct 12% low speed wind tunnel test.
Sep 02	Conduct 12% high-speed wind tunnel test.
Sep 02	Distributed Control, AWACS/JSTARS, lab demonstration complete.
Nov 02	Demo & Evaluation of HIS Devices in lab and maritime environment.
Dec 02	RCS Signature demonstration complete.
Jul 03	Complete deck operations demonstration.
Jul 03	Complete MCS Navy C4I infrastructure integration demonstration.
Oct 03	Contractor X and Y UDS construction complete.
Dec 03	Conduct Next Generation SAR technology flight demonstration.

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Dec 03 Contractor Y final UDS ground tests complete.

Hybrid Cycle and Rocket Engine:
Aug 02 Complete conceptual design, trade-studies.
Sep 03 Complete initial reusable technology demonstrations.

Quiet Supersonic Platform (QSP):
Jun 01 Complete preliminary propulsion systems studies.
Sep 01 Report results of QSP technology assessment and system integration studies.
Jan 02 Complete airframe and detailed propulsion systems studies.

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.

Space Object Identification System (SOIS):
May 02 Complete initial requirements review.
Sep 02 Select candidate technology to pursue.

Satellite Protection and Warning (SPAWN):
Jan 02 Select team for micro/nanosatellite development and fabrication.
May 02 Complete threat characterization and initial requirements review; identify candidate sensor systems.
Oct 02 Conduct system level Preliminary Design Review; begin ordering long lead times.

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COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	245.187	219.467	177.264	159.867	166.400	179.900	168.900	179.900	Continuing	Continuing
Uncooled Integrated Sensors MT-03	15.599	16.798	6.930	7.000	0.000	0.000	0.000	0.000	0.000	N/A
Electronic Module Technology MT-04	51.429	39.965	33.772	31.067	35.075	46.775	46.815	46.775	Continuing	Continuing
Tactical Information Systems MT-05	22.488	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Centers of Excellence MT-07	5.334	5.213	4.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Manufacturing Technology Applications MT-08	14.580	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Advanced Lithography MT-10	43.969	55.747	25.013	25.000	25.000	25.000	0.000	0.000	0.000	N/A
MEMS and Integrated Micro-systems Technology MT-12	70.946	48.113	37.590	24.000	24.025	10.825	10.825	10.825	Continuing	Continuing
Mixed Technology Integration MT-15	20.842	53.631	69.959	72.800	82.300	97.300	111.260	122.300	Continuing	Continuing

(U) Mission Description:

(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

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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.

(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 Photonic Wideband Semiconductor Technology and the Superconducting Hybrid Power Electronics (SuperHyPE) 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 seed, 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. Also included in this project is the Anti-Tamper initiative which is to protect selected critical technologies in U.S. weapons systems.

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(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 2002.

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

	FY2000	**FY 2001**	**FY 2002**
Previous President's Budget	252.388	191.800	188.264
Current Budget	245.187	219.467	177.264

(U) Change Summary Explanation:

FY 2000	Decrease reflects below threshold reprogramming, minor program repricings, and SBIR reprogramming.
FY 2001	Increase reflects congressional adds for Laser Point Source Stepper, Laser Plasma X-Ray Lithography, Defense Techlink, Center for Advanced Microstructures, MEMS for Deep Silicon Etching, Advanced Lithography, and the Navy Center of Excellence partially offset by the Section 8086 reduction and the government-wide rescission.
FY 2002	Decrease reflects the net result of the phase down of the Advanced Lithography project in preparation for technology transition partially offset by the expansion of the Biofluidics program in the Mixed Technology Integration project and the increase for the digital control program.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Uncooled Integrated Sensors MT-03	15.599	16.798	6.930	7.000	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. Thermal Imaging Devices will develop new imaging at the theoretical limit, (five to fifty times increase over current uncooled devices), achieving high performance in extremely small, low power configurations and demonstrating technology to open new applications for imaging devices.

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

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

- Uncooled Imaging Sensors & Devices. ($ 7.599 Million)
  - Demonstrated 480x640-uncooled arrays with < .05 milli-Kelvin, 1 mil pixel.
  - Transferred 480x640 uncooled infrared sensor to Army missile seeker program.
  - Conducted field evaluation of high sensitivity uncooled infrared sensor with low light sensor for ground operations.

- Thermal Imaging Devices. ($ 8.000 Million)
  - Demonstrated non-contact read-out devices and characterized sensitivity/noise sources.
  - Demonstrated non-contact imaging array with thermal sensitivity of 100 milli-Kelvin.

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(U) **FY 2001 Plans:**

- Uncooled Imaging Sensors & Devices. ($ 12.826 Million)
  - Demonstrate 100 gram imaging sensor with performance acceptable for micro-air-vehicles.
  - Optimize read-out structure to read signals with short (approximately 1 msec.) integration time.
  - Conduct three-D thermal imaging phenomenological experiments and studies.

- Electro-Optics IR Technology Center. ($ 3.972 Million)
  - Develop 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.
  - Incorporate innovative detector and signal processor designs to maximize operating temperature, while maintaining the target discrimination capability at the maximum system range.

(U) **FY 2002 Plans:**

- Uncooled Imaging Sensors & Devices. ($ 6.930 Million)
  - Incorporate high responsitivity materials into detector structure.
  - Integrate materials and microstructure into imaging device.

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

- Not Applicable

(U) **Schedule Profile:**

Plan	Milestones
Aug 01	Demonstrate 100 gram imaging sensor with performance acceptable for micro-air-vehicles.

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Dec 01	Demonstrate 50-gram sensor with sensitivity of 20 milli-Kelvin.
Jan 02	Incorporate high responsitivity materials into detector structure.
Mar 02	Integrate materials and microstructure into imaging device.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Electronic Module Technology MT-04	51.429	39.965	33.772	31.067	35.075	46.775	46.815	46.775	Continuing	Continuing

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

(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.

(U) 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 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), the Wide Band Gap RF Semiconductor 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 is exploring approaches to 'print' MEMS devices on large surfaces.

(U) The Photonic Wide Band Gap RF Semiconductor Technology program will develop 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)

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material, and highly efficiently active region material suitable for ultraviolet emission and exploit these results to enable the development of heterojunction bipolar transistors (HBT).

(U) The Superconducting Hybrid Power Electronics (SuperHyPE) program will demonstrate a new paradigm in power electronics for the "all electric" vehicles of the future. Combining superconductivity, cryogenics and power electronics for self contained platforms will provide a) improved controllability via rapid response and ease of interface with digital control systems, b) significantly reduced maintenance, c) reduced complexity through reduced number of energy transformations and reduced support requirements, d) increased efficiency through less energy conversion and improved primary power sources, e) new applications such as pulsed energy systems, directed energy weapons, rail guns, and f) fully automatic systems to reduce personnel needs. These hybrid systems offer significant increases in specific power density, which provide weight, and volume savings that scale with the overall size of the system. This can easily translate to an order or magnitude saving for a moderate size system (5000 HP) and significantly more for large systems (>20,000 HP).

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

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

- Photonic A/D. ($ 14.787 Million)
  - Evaluated alternative photonic clock, optical sampler and quantizer module designs for photonic A/D converters operating in the 10-100 Giga-sample-per-second range.
  - Identified high impact applications for this technology.

- Distributed Robotics. ($ 12.378 Million)
  - Demonstrated feasibility of a variety of multiple robots (<5cm) operating in specific military environments and their ability to adapt to varying environments and missions.
  - Demonstrated probability of mission success improved by distributed functionality.

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- Composite CAD. ($ 9.945 Million)
  - Completed the development of systems software design and simulation capabilities for mixed technology micro-systems, including MEMS-enabled designs and micro fluidic (Micro-Flumes) designs. The ultimate goal of the complete systems design capability is to enable mixed technology systems-on-a-chip.
  - Provided mixed technology design libraries, models and test structure data to improve design quality, development time and ability to reuse designs.

- Molecular-level Large-area Printing (MLP). ($ 14.319 Million)
  - Concentrated on the development and choice of non-conventional large-area, MLP techniques for a demonstration system.
  - Established overlay capabilities for MLP.

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

- Photonic A/D. ($ 15.459 Million)
  - Complete initial photonic analog/digital (A/D) converter evaluation and finalize design for demonstration module.
  - Demonstrate key photonic technologies.

- Distributed Robotics. ($ 12.678 Million)
  - Demonstrate multiple robots with overall functionality and probability of mission success improved by integration of optimized control strategies.

- Molecular-level Large-area Printing (MLP). ($ 11.828 Million)
  - Demonstrate and characterize 10,000 x 100 pixel density array on a spherical surface.

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

- Photonic A/D. ($ 8.557 Million)
  - Complete photonic analog/digital converter technology development.

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- 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. ($ 4.749 Million)
  - Complete current contracts on micro robot developments.
  - Deliver prototype hardware and final reports.
  - Demonstrate with operational military users.

- Photonics Wide Band Gap RF Semiconductor Technology. ($ 10.000 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). ($ 10.466 Million)
  - Identify target power modules and platform for maximum benefit of hybrid approach.
  - Initiate design for integrated hybrid power module.

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

- Not Applicable.

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(U) Schedule Profile:

Plan	Milestones
Jul 01	Demonstrate and characterize 10,000-x 100-pixel density array on spherical surface.
Aug 01	Demonstrate multiple robots with overall functionality and probability of mission success improved by integration of optimized control strategies.
Jul 02	Develop high power high temperature devices.
Sep 02	Demonstrate high temperature operation of integrated power switches.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001

APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-07

COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Centers of Excellence MT-07	5.334	5.213	4.000	0.000	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 Te chlink Rural Technology Transfer Project.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Advanced Flexible Manufacturing. ($ 3.834 Million)
  - Expanded the Institute for Advanced Flexible Manufacturing's web-based electronics supply chain support to include 150 small manufacturers who now have access to Defense on-line procurement activities.

- Defense Techlink Rural Technology Transfer Project. ($ 1.500 Million)
  - Provided funding for the Defense Techlink Rural Technology Transfer Project.

(U) FY 2001 Plans:

- Advanced Flexible Manufacturing. ($ 3.972 Million)
  - Continue to expand the web based electronics supply chain and increase the number of manufacturers who have access to, and qualify for, Defense acquisitions.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-07

- Defense Techlink Rural Technology Transfer Project. ($ 1.241 Million)
  - Provide funding for the Defense Techlink Rural Technology Transfer Project.

(U) <u>FY 2002 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 01	Complete Defense Techlink Rural Technology Transfer Project.
Sep 02	Complete assessment and transition of the Institute for Advanced Flexible Manufacturing from DoD to state/private support.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)										DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development					R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-10					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Lithography MT-10	43.969	55.747	25.013	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 ?m 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.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Sub 0.1 Micron Lithographies. ($ 21.969 Million)

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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-10

- Developed key tool components, materials and processing to accelerate the availability of emerging lithography technologies beyond 193 nm. Efforts included maskless (electron beam, ion beam) approaches and projection technologies, using optical, electron, x-rays and extreme ultraviolet.

- Support Technologies. ($ 16.000 Million)
  - Developed support technologies, to include mask technology, resists and metrology.
  - Developed innovative optics designs, architectures and new materials, and processing beyond the evolutionary trends in the industry.

- Laser Plasma X-ray Source. ($ 5.000 Million)
  - Continued laser plasma x-ray source technology.

- Point Source Lithography. ($ 1.000 Million)
  - Continued point source lithography development.

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

- Sub 0.1 Micron Lithographies. ($ 23.031 Million)
  - Demonstrate key components of maskless wafer writer and key components for lithography of 0.07 micron features.

- Support Technologies. ($ 19.112 Million)
  - Accelerate technology developments in the lithography exposure sources and supporting (cross-cutting) technologies needed for microelectronics fabrication.
  - Develop 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)
  - Continue laser plasma x-ray source technology.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-10

- Point Source Lithography. ($ 3.674 Million)
  - Continue point source lithography development.

- Advanced Lithography Mask Development. ($ 4.965 Million)
  - Continue lithography mask development.

(U) **FY 2002 Plans:**

- Sub 0.1 Micron Lithographies. ($ 15.013 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.

- Support Technologies. ($ 10.000 Million)
  - Develop mask technology (writing, inspection and repair), resists and metrology for lithography for sub 0.1 micron.
  - Develop resists that will emphasize thinner resists appropriate for emerging exposure sources.

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

- Not Applicable.

(U) **Schedule Profile:**

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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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)										DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development					R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-12					
COST *(In Millions)*	FY 2000	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	70.946	48.113	37.590	24.000	24.025	10.825	10.825	10.825	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-

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-12

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

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

- MEMS Devices and Processes. ($ 18.817 Million)
  - Developed new devices and processes that survive extremely harsh environments and facilitated the integration of micro-mechanical as well as micro-chemical systems into electronic circuits. These new devices include micro power sources, mechanical-microprocessor units, micro actuators, communication components, MEMS aerodynamic pressure sensors on flexible adhesive tape substrate; modular, monolithically integrated MEMS Inertial Measuring Unit (IMU); and MEMS high-temperature sensor and actuator arrays.
  - Demonstrated micro devices that will reduce communication equipment to the size of a credit card; optimized the aerodynamics of an airplane wing for lift and drag, provided intelligence to machine components to allow them to report their condition and state of readiness (e.g., "smart wheel bearings"), and increased the resistance of jamming of GPS used on smart munitions.
  - Integrated power sources with the MEMS devices and expanded the use of MEMS in fluidic applications.

- MEMS System Design and Development Phase II. ($ 16.211 Million)
  - Initiated technology demonstrations relevant to micro airborne sensor/communicator platforms and chemically powered remote sensors, subsystems for Pico Satellites, electromechanical signal processing and nanoelectromechanical systems.

- CAMD. ($ 3.888 Million)
  - Continued micro device manufacturing processes at the Center for Advanced Microstructures and Devices (CAMD).

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- MEMS MicroPower Generation. ($ 23.030 Million)
  - Demonstrated feasibility and practical limits of converting chemical energy into electrical energy on the micro-scale using MEMS technology. The goal is to replace primary and rechargeable batteries with micropower generators that have at least one order of magnitude higher energy density, and thus drastically reducing weight and volume of power sources.
  - Developed high-energy density power generation on micro-scale from fuels.
  - Developed stand alone, remotely distributed MEMS sensor networks.

- Bio-Fluidic Chips (BioFlips). ($ 9.000 Million)
  - Designed microscale fluidics integrated with optical and/or electronic detection to monitor cellular activities of body fluids.
  - Designed chip interface with bio-fluids for continuous sampling and fluids delivery.
  - Developed on-chip reagent storage and reconstitution.

(U) FY 2001 Plans:

- MEMS Micro Power Generation. ($ 19.694 Million)
  - Demonstrate chip-level integration of components for fuel processing, thermal management, energy conversion and exhaust management for micropower generation. Enable stand alone, remotely distributed microsensors with built-in power supply and RF communication in addition to various sensing functions.
  - Develop MEMS free-piston knock engine.
  - Develop an integrated fuel cell and fuel processor for microscale power generation from liquid fuels.
  - Develop integrated chemical fuel microprocessor for power generation in MEMS applications.
  - Develop 3-D monolithically fabricated thermoelectric micro generator.

- CAMD. ($ 2.731 Million)
  - Continue micro device manufacturing process at the Center for Advanced Microstructures and Devices (CAMD).

- Deep Silicon Etching. ($ 7.944 Million)
  - Complete MEMs Deep Etching program in conjunction with the Army Research Laboratory.

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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-12

- Bio-Fluidic Chips (BioFlips). ($ 17.744 Million)
  - Develop closed-loop bio-fluidic chips to regulate cellular transduction pathways and precise dosage of chemicals/drugs/ reagents/enzymes.
  - Fabricate and test individual microfluidic chip components and integrated sensors for flow control.
  - Manipulate (pump/valve/sense) bio-fluids in integrable microfluid components.

(U) FY 2002 Plans:

- MEMS Micro Power Generation. ($ 19.789 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). ($ 17.801 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.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

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Plan	Milestones
Sep 01	Demonstrate atomic resolution data storage.
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.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)						DATE June 2001			
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 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Mixed Technology Integration MT-15	20.842	53.631	69.959	72.800	82.300	97.300	111.260	122.300	Continuing	Continuing

(U) Mission Description:

(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, a paradigm that addresses many of the present and future needs of the DoD. 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) 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 'match-book-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

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microwave components could provide a highly integrated, portable analytical instrument to monitor the battlefield environment, the physical 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 Engineered Molecular Flow Devices or BioFluidics program is developing and testing chip scale molecular flow control arrays for sensing contaminants.

(U) The Nano Mechanical Array Signal Processors (NMASP) program 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) 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

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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 2000 Accomplishments:</u>

- 3-D Imaging Devices. ($ 7.109 Million)
  - Initiated program to develop new high speed imaging device technology to rapidly acquire a high-resolution 3-D image of a tactical target at ranges of 7-10 kilometers increasing identification range of tactical targets, especially from fast moving platforms.
  - Developed near infrared materials with point defect density less than 1000/sq cm.
  - Demonstrated 4x4 array of detectors with gain of 30 at 1 GHz.
  - Completed investigation of novel high gain detector concept.

- Steered Agile Laser Beams (STAB). ($ 6.630 Million)
  - Initiated program to develop compact, lightweight, man-portable, electronically steered lasers to replace large, heavy gimbal mounted lasers in lasercom links and smart weapon target designators.
  - Developed small, lightweight laser beam scanner system technologies for replacement of gimbaled mirror systems.
  - Initiated system design and component specifications; selected system design.

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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

- RF Lightwave Integrated Circuits (RFLICS). ($ 7.103 Million)
  - Initiated program to demonstrate, with heterogeneous integration, lightwave and RF technologies to route, control and process analog RF Signals in the 0.5-50 GHz range.
  - Developed RF-Photonic modules to enable links with better than zero net RF loss from input to output.
  - Developed and demonstrated optically integrated modules capable of performing complex RF functions such as signal channelization or single chip generation of multiple RF signals.

(U) FY 2001 Plans:

- 3-D Imaging Devices. ($ 20.980 Million)
  - Complete design of high-speed electronics for sub-nanosecond detection.
  - Initiate experiments in exploiting and adapting emerging technology in nanofabrication to create nano resonators by chemical and physical transfer of materials on nano-scale patterns.
  - Integrate high-speed electronics with 5x5-detector array and integrate into brass board imaging system.
  - Demonstrate laboratory imaging with 5x5 array.
  - Select detector design for 128x128 3-D imaging array.

- Steered Agile Laser Beams (STAB). ($ 17.825 Million)
  - Develop 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.
  - Fabricate beam steering emitters and detectors.

- RF Lightwave Integrated Circuits (RFLICS). ($ 14.826 Million)
  - Focus program on identified key applications for integrated RF-Photonic modules and produce initial prototypes and demonstrate methods for evaluation of their performance.
  - Initiate 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.

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– Down-select among technology options and develop prototype module for demonstration.

(U) **FY 2002 Plans:**

- 3-D Imaging Devices. ($ 11.625 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.

- Steered Agile Laser Beams (STAB). ($ 14.357 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.

- RF Lightwave Integrated Circuits (RFLICS). ($ 11.977 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). ($ 11.000 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.

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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

- Digital Control of Analog Circuits. ($ 7.000 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) for Military Platforms. ($ 6.000 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.
  - Develop AT technology throughout the Radio/Frequency/Gallium Arsenide and Digital Gallium Arsenide domains.

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

- Not Applicable.

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

<u>Plan</u>	<u>Milestones</u>
3-D Imaging:	
Jun 02	Demonstrate range imaging at eye safe wavelengths.

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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

STAB:

Aug 01	Fabricate beam steering emitters and detectors.
Jul 02	Fabricate laser beam steering components.
May 03	Complete prototype design studies.

RFLICS:

Aug 01	Demonstrate integrated RFLICS functions such as channelizer with 10 GHz selectivity over 0-50 GHz bandwidth.
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 ±20%, and to ±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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APPROPRIATION/BUDGET ACTIVITY	R-1 ITEM NOMENCLATURE
RDT&E, Defense-wide BA3 Advanced Technology Development	Command, Control and Communications Systems PE 0603760E, R-1 #47

COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	175.665	128.778	117.451	104.480	107.700	108.100	103.100	103.100	Continuing	Continuing
Command & Control Information Systems CCC-01	98.776	78.133	67.331	58.234	70.188	73.263	67.263	67.263	Continuing	Continuing
Information Integration Systems CCC-02	76.889	50.645	50.120	46.246	37.512	34.837	35.837	35.837	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 Command and Control Information Systems project is developing the technologies necessary to facilitate joint campaign planning and control throughout the battlespace. Programs include: the Joint Force Air Component Commander (JFACC), the Man and Machine Command and Control Program, the Information Assurance Science and Engineering Tools; Organically Assured and Survivable Information Systems; the Advanced Intelligence, Surveillance and Reconnaissance (ISR) Management (AIM) program; the Control of Agent-Based Systems program; Project Genoa; the Active Templates program; and Tera Hertz Operational Reachback (THOR) program.

(U) The Information Integration Systems project will develop the technologies necessary to ensure that the enhanced information required by battlefield combatants is available on a near real-time basis. Programs addressed in this project include: the Dynamic Database (DDB) program; the Airborne Communications Node (ACN) program; the Command Post of the Future program; Symbiotic Communications; the Next Generation (XG) program; and Advanced Speech Encoding program.

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

	FY 2000	FY 2001	FY 2002
Previous President's Budget	185.926	128.863	130.688
Current Budget	175.665	128.778	117.451

(U) Change Summary Explanation:

FY 2000 Decrease reflects several program repricings, the phase out of AICE and BADD programs and SBIR reprogramming.

FY 2001 Decrease reflects the Section 8086 reduction and the government-wide rescission.

FY 2002 Decrease reflects the completion of the Dynamic Database and Information Assurance Science and Engineering Tools programs.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Command & Control Information Systems CCC-01	98.776	78.133	67.331	58.234	70.188	73.263	67.263	67.263	Continuing	Continuing

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

(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) The Joint Force Air Component Commander (JFACC) program has addressed critical issues in military command and control (C2), specifically joint and coalition air operations. In the earlier phases of the program, it was noted that as each C2 element (observation, orientation, decision and execution) was driven toward progressively shorter timelines, dynamic instabilities in the decision loop became the key challenge to practical implementation of any new generation of C2 systems. JFACC developed and validated new C2 architectural concepts and appropriate control strategies with the ability to: (1) rapidly and efficiently respond to varying objectives and guidance, time constraints, changeable resources, erratic hostile responses, asymmetric threats and unpredictable anomalies (Agility); (2) proactively manage destabilizing events, such as time critical targets, while simultaneously avoiding undesirable long-and short-term effects, to include disruptive and inefficient impacts on downstream plans and operations (Stability); and (3) adapt to the wide spectrum of military conflicts and activities (Flexibility). The last phase of the JFACC program demonstrated the efficacy of using the mathematics and science of control theory as a foundation for generating a dynamic military C2 architecture. Final demonstrations and evaluations complete in FY 2001.

(U) Building upon the results of previous C2 efforts, the Man and Machine Command and Control (M2C2) program will generate decision and control-based software tools within dynamically adaptable C2 architectures to allow the commander to understand and make critical decisions within

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a complex, time-constrained environment. The M2C2 program will enable the commander to institute autonomic responses to a wide variety of threats in the presence of resource constraints and to issue guidance to both manned and autonomous entities in a coordinated manner at all levels of the C2 hierarchy. This program will provide the commander with the technological C2 tools that will allow real-time response in a dynamic, complex, high tempo environment.

(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 assure the availability of associated services – particularly in a stressed environment. In FY 2000, the program that addressed such key issues, Information Assurance (IA), ended. The Information Assurance Science and Engineering Tools (IASET) program, while incorporating lessons learned from the IA program, addressed the assurance problem by investigating the underlying science that would allow a formal understanding of the problem at hand. The Information Assurance and Survivability programs, of which IASET was a part, were thoroughly reviewed in FY 2000 to ensure that information assurance and survivability needs of DoD are being met. As a result of the review, IASET will complete investigations in FY 2001 with key results being transferred to the Cyber Panel and Fault Tolerant Networking programs funded in PE 0602301E, Project ST-24.

(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 (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.

(U) The Control of Agent-Based Systems (CoABS) program will explore the ability to rapidly assemble a set of disparate information systems into a coherently interoperating whole. This will be done without having to redesign legacy systems and will include 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 the multi-systems integration and in controlling the information flow

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to alleviate bandwidth saturation and degraded quality of service. The CoABS program will demonstrate and deploy a middleware-based approach, and eventual toolkit, to support interoperable of heterogeneous systems in coalition operations and will enable the interaction of military and non-military resources in critical operations.

(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 key enabling technologies are: knowledge discovery of critical information from unstructured multimedia sources; structured argumentation to capture and present reasoning from evidence to conclusion; and a comprehensive corporate memory that will enable comparison of critical information across situation, time and organization. The current clients for components of the prototype system are Joint Chiefs of Staff and Defense Intelligence Agency, Office of Assistant Secretary of Defense (International Security Affairs), Joint Counter-intelligence Assessment Center, and Command-in-Chief Pacific (J3).

(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

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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 will 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 megabit-per-second connectivity and reachback to and from terrestrial and maritime forces will be demonstrated.

(U) The Organically Assured and Survivable Information Systems (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. Further investigation of the theory of information survivability and metrics will be pursued in conjunction with Cyber Panel and Fault Tolerant Networks to provide the scientific foundation for information survivability technologies.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Joint Force Air Component Commander (JFACC). ($ 20.948 Million)
  - Developed a reconfigurable model that simulates the dynamic phenomena within the military air operations enterprise.
  - Experimentally investigated the stability effects of new control technologies and C2 architectures incorporated within the air operations domain.
  - Evaluated performance improvements gained by implementing combined optimal asset allocation and route planning for simulated air operations.

- Information Assurance. ($ 35.500 Million)
  - Demonstrated automated capabilities that enable dynamic, secure collaboration between enclaves including data and invocation flow rules.
  - Demonstrated real-time, finer-grained advanced attack detection and response at the application layer, operating system and network infrastructure. Coupled advanced attack detection capabilities with automated system security and administration tools to enhance integrated monitoring and control of network services, detected attack status, and system configuration.

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- Dynamically and automatically managed allocation of components and resources to reconstitute critical functions that have degraded.
- Demonstrated security policy interoperability between enclaves.
- Explored knowledge base approach to adaptive systems management.
- Improved assurance measurement and risk analysis by establishing value functions for user data.
- Enhanced object assurance granularity by augmenting Common Object Request Broker Architecture Security (CORBASEC).
- Completed selection of basic Information Assurance Science and Engineering Tools (IASET) architecture for incorporation into an integrated design environment.
- Conducted initial IASET experiments with information assurance design methodologies emphasizing the application of science-based metrics in assessment activities.

• Advanced ISR (Intelligence, Surveillance and Reconnaissance) Management (AIM). ($ 7.038 Million)
  - Developed collection, exploitation and dissemination synchronization techniques to link all phases of ISR management in support of the warfighter.
  - Developed Multi-Asset Synchronizer to provide near real time organization and synchronization of multiple disparate sensor assets; installed and operated at U.S. Southern Command.
  - Initial automated collection strategy tools passed to the Integrated Collection Management efforts in the Defense Intelligence Agency.
  - Conducted operational "proof of concept" experiments with prototype AIM components at U. S. Southern Command.
  - Developed and demonstrated a preliminary capability to optimally allocate distributed ISR resources over extended period of time horizons using a market-oriented programming approach.
  - Conducted technical assessments of emerging AIM technologies, including multi-asset synchronization and strategy development.

• Control of Agent-Based Systems (CoABS). ($ 16.326 Million)
  - Developed and demonstrated a flexible information infrastructure and an interoperability tool called the Agent Grid.
  - Supported the dynamic deployment of complex applications for dynamic domains such as military command and control. These applications require the composability, adaptability and autonomy provided by software agents interoperating in dynamic, mixed-initiative teams with human users. This Agent Grid provides access to shared protocols and ontologies, mechanisms for describing agents' capabilities and needs, and services that support interoperability among agents at flexible levels of semantics distributed across a network infrastructure.

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- Project Genoa. ($ 11.422 Million)
  - Knowledge Discovery: Transitioned a knowledge discovery tool to Intelink Management Office; developed and implemented information extraction from text and extensive use of innovative visualization of complex information relationships.
  - Structured Argumentation: Refined crisis models, developed tools for scenario based, alternative futures reasoning, and developed collaborative option generation. Continued work on meeting transcription. Began development ability to navigate and play back corporate memory.
  - Experimented with products from Information Assurance projects to enable a multi-intranet system to operate at mixed security levels.
  - Continued evaluation by users from the national security community.

- Active Templates. ($ 7.542 Million)
  - Developed and encoded templates of standard operating procedure, which integrated causal model capability to show how constraints, event triggering, inference and uncertain reasoning can be utilized for fast crisis planning and execution.
  - Created a flexible networked architecture that supports template linking, dynamic connections, consistency management and dynamic information sharing. Characterized performance in terms of connection speed, message throughput and consistency maintenance.
  - Developed and demonstrated temporal plan editor and execution monitoring tool now adopted by several Special Operations organizations.

(U) **FY 2001 Plans:**

- Man and Machine Command and Control (M2C2) (Formerly Dynamic Command and Control). ($ 10.924 Million)
  - Develop design specifications for selected decision-making tools (controllers and state estimators) within a dynamic, multi-faceted architecture.
  - Initiate an extensive library of operational "plant" models, which can support a wide range of computational to operational experiments.
  - Experimentally evaluate the command and control architecture and design concepts produced during this phase.
  - Continue to explore new and innovative theories, techniques, and tools for enabling agile and stable military operations.
  - Develop technology, algorithms and software tools for team composition and allocation to military operational tasks based upon collective goals.

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- Joint Forces Air Component Commander (JFACC). ($ 7.000 Million)
  - Complete experimentation and evaluate effectiveness of C2 architectures incorporated, via simulation, into air operations systems.

- Information Assurance Science and Engineering Tools (IASET). ($ 20.831 Million)
  - Develop 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.
  - Organically Assured and Survivable Information Systems (OASIS)
    > Demonstrate real-time execution monitoring techniques and tools to mitigate malicious mobile code.
    > Prototype demonstration of integrity mark technology for protection of sensitive imagery.
    > Beta release of certifying compilers and security proof generators and checkers.
    > Investigate new approaches to intrusion tolerance based on data, spatial, temporal and analytical redundancy and resource allocation; identify relevant challenge problems.
    > Demonstrate self-protecting mobile agent prototype.
    > Develop architecture for building intrusion tolerant systems from potentially vulnerable components by applying existing fault-tolerant approaches to intrusion tolerance support layered defenses, and provide resilience to attacks.

- Advanced ISR (Intelligence, Surveillance and Reconnaissance) Management (AIM). ($ 9.667 Million)
  - Explore new ISR system architectures and technologies to increase effectiveness and reduce man loading in tactical as well as planning applications.
  - Conduct operational evaluation of AIM automated collection Strategy Developer (SD) and Multi-Asset Synchronizer (MAS) technologies with U.S. Southern Command. Employ MAS as an off-line, real-time, component of operational exercise Unified Endeavor.
  - Expand SD and MAS capabilities to include tasking of GMTI and SIGINT sensors. Characterize 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.
  - Evaluate 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. Establish a collaborative engineering environment to conduct AIM/DDB experimentation.

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- Partner 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.
- Experiment with NRO to introduce AIM technologies to their advanced concept development environment.

• Control of Agent-Based Systems (CoABS). ($ 12.116 Million)
- Deploy agent technologies and tools using the Agent Grid for use in ACTD and Naval Fleet Battle Exercises activities.
- Empirically demonstrate efficacy of approach in these realistic military domains.

• Active Templates. ($ 9.696 Million)
- Integrate and demonstrate multiple templates merging by users to update information, add dependencies and attach problem-solvers.
- Demonstrate initial capability to automatically and continuously compile geophysical information from different databases and other network information sources.

• Project Genoa. ($ 7.899 Million)
- Complete development of corporate memory, future scenario generation tools and tailored presentation tools.
- Develop and validate emerging concepts from collective reasoning applied to the asymmetric threat.
- Investigate the use of intelligent agents to automate functions where possible.
- Incorporate changes resulting from client evaluation in real world asymmetric environment.

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

• Man and Machine Command and Control (M2C2). ($ 10.416 Million)
- Demonstrate prototype controllers, focusing on managing temporal and spatial battlespace dynamics.
- Model ~20 entities with simple, tactical-level objectives and minimal battlespace uncertainty.
- Evaluate potential for sensitivity analysis of decision metrics, course-of-action recommendations and adversarial inference information to provide useful data content to the Services.
- Instantiate standard objects within an experimental framework with common messaging features.

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- Advanced ISR (Intelligence, Surveillance and Reconnaissance) Management (AIM). ($ 9.893 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 in combination with quantitative data driven needs, for use in multi-user/multi-mission environments.
  - Conduct experimentation of AIM at Joint Battle Center.
  - Transition multi-asset synchronization and strategy developer tools to airborne and overhead collection systems including classified ISR management programs.

- Control of Agent-Based Systems (CoABS). ($ 9.893 Million)
  - Release Agent-Grid code and components tailored to military user needs and evaluated in military applications.
  - Evaluate in military applications including coalition operations and intelligence.

- Active Templates. ($ 9.893 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. ($ 0.989 Million)
  - Transition components to user agencies such as Joint Chiefs of Staff, Defense Intelligence Agency, OSD(C3I), OSD(ISA), etc.

- Organically Assured and Survivable Information Systems (OASIS). ($ 16.247 Million)
  - Develop an experimental intrusion tolerant database from 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.

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- 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.

- Tera Hertz Operational Reachback (THOR). ($ 10.000 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 υm wavelength in the laboratory.
  - Investigate the use of steerable agile beam technology to eliminate the gimbols.
  - Complete system trade studies for a maritime terminal.

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

- Not Applicable.

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

<u>Plan</u>	<u>Milestones</u>
Jul 01	Demonstrate CINC to tactical level integrated combined arms execution command and control with small unit synchronizing toolkit.
Jul 01	Experiment with AIM/DDB technologies to explore utility for Dynamic Tactical Targeting applications.
Aug 01	Experiment in collaborative environment with NRO/ACDE program at TIC.
Aug 01	Initiate the development of selected prototype C2 tools from new control strategies and concepts.

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Sep 01	Demonstrate that users can tailor their own templates, update information, add dependencies and attach problem-solvers. Show that active template technology is scalable in that 50 templates have been built. Show that planning speed doubles and plan quality improves.
Dec 01	Transition AIM technology as basis for tactical level control of dynamic targeting.
Dec 01	Release product quality Agent Grid code and components tailored to military user needs and evaluated in military applications.
Jan 02	THOR solicitation for system integrator task.
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.
Mar 02	THOR technology tasks contract award.
Apr 02	THOR system integrator contract award.
Jul 02	Conduct experimentation of AIM technology at operational command (e.g. Joint Battle Center (JBC)).
Sep 02	Show six-fold increase in execution replanning using Active Templates attached to live data feeds from battlefield sensors.
Sep 02	Transition AIM technology to DIA, CICMP.
Oct 02	THOR solicitation for core technology tasks.
Feb 03	Experimentally validate M2C2 system framework and prototype designs and concepts.
Jun 03	THOR preliminary design review.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Information Integration Systems CCC-02	76.889	50.645	50.120	46.246	37.512	34.837	35.837	35.837	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 program.

(U) The overarching goal of the Dynamic Database (DDB) program is 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. A Sensor History Database stores and maintains the output from the Change Detectors, and retains the raw sensor data as a pedigree. All-source Track and ID Fusion processes were developed to establish a derived Situation History Database by filtering tactically significant changes from the Sensor History Databases. Significant situation changes are shared throughout the DDB system through a scaleable High Performance Data Server, which connects the Sensor History Database nodes, algorithm applications, processors and information repositories. DDB “normalcy models” were then developed to establish conditions for change detection, to trigger external processes when conditions meet posted criteria, propagate updates/alerts across DDB processors, and support queries and searches of associated databases. 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 concludes in 2001 and the technology demonstrated, to include the DDB-AIM experiment, will provide the underpinnings of the Dynamic Tactical Targeting (DTT) program beginning in FY 2002 (PE 0603762E, Project SGT-04, Sensors and Exploitation Systems).

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(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 (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 uncertainity, often called the 'fog of war' slows down and degrades the quality of command decisions. Radical improvements in gaining 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 in order 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 hardware and software components that can be quickly configured and tailored to various command environments (stationary and mobile), at different echelons of 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

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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 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 Digital Terrain Elevation Data (DTED) Level 5 precision will be conducted.

(U) The objective of the Battlefield Awareness and Data Dissemination (BADD) Advanced Concept Technology Demonstration (ACTD), which concluded in FY 2000, was to integrate and demonstrate information management and battlefield awareness technologies that allow operational users to easily access and exploit an expanded, massive information flow and for commanders to manage it.

(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. 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 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 provided. 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

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

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

- BADD ACTD. ($ 5.432 Million)
  – Completed the integration effort with DISA's products. Fielded BADD/DISA products to selected CINCs six months prior to the end of the ACTD. Continued upgrading capability (based on warfighter input/feedback) to provide a more enhanced version to the CINCs in the latter part of the fiscal year.
  – Provided interfaces that will allow other ACTDs and programs to take advantage of the BADD capabilities.
  – Upgraded the software to be compliant with the DISA next iteration of the DII COE. Transitioned capability to DISA.

- AICE. ($ 1.569 Million)
  – Completed closeout of AICE in concert with BADD ACTD transition.

- Dynamic Database (DDB). ($ 25.590 Million)
  – Continued development of the Ground Moving Target Indicator (GMTI), Signals Intelligence (SIGINT) and Imagery Intelligence (IMINT) Sensor History Database (SHDB) object schema to include pedigrees that automatically map entity-level situation assessments to multi-sensor source data through a scaleable High Performance Data Server (HPDS). Visible Electro-Optic (EO) data was added to the stored data-types.
  – Developed and validated "normalcy models" of GMTI, SIGINT and IMINT data over time. These normalcy models are used to set thresholds in remote sensor "trip wires" at strategic locations in the battlespace. Increased activity in one or more of the sensor types will trigger DDB to invoke algorithms for additional processing and cue operators to perform analysis of situation.
  – Demonstrated DDB component technologies and a loosely coupled system capability with the following results:
    –– *System Modeling* - Quantified fusion gain as a function of sensor performance (revisit time, resolution, etc.)
    –– *Registration* - proof of concept to automatically perform co-registration of GMTI, SIGINT, SAR, EO and IR data

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–– *IMINT* - Fusion of SAR and EO object and image change detection.
––– 100 times reduction in false alarms for open area conditions.
––– Ten times reduction in false alarms for partially obscured targets.
–– *GMTI* - Five times improvement in track life continuity.
–– *SIGINT* - Novel techniques for monitoring the battlespace environment.
––– Emissions density and profile of militarily significant events with probability of detection of 93 percent / probability of false alarm of ten percent.
––– Reconstructed tactical communication networks resulting in 68 percent of links identified.
–– *Model Based Classifier* - First multi-phenomenology (SAR, EO, IR) processor.
–– *Target Models* - First DoD common multi-sensor target database containing 33 SAR, 18 EO and three IR targets derived from a common parent CAD model.
–– *All-source Track and ID Fusion*
––– First move-stop-move tracking capability.
––– Two to five times reduction in track fragmentation.
––– 60 to 90 percent probability of correct association from fused GMTI, SIGINT and IMINT kinematic and identity features.
–– *Force Level Change Detection* - proof of concept to track and identify a platoon sized group with probability of detection greater than 95 percent and false alarm rate of less than five percent.
– Completed and demonstrated the DDB architecture design in the Component Experimentation and System Integration Laboratory (CESIL).

• Command Post of the Future (CPOF). ($ 14.129 Million)
– Produced technology in the areas of automated visualization, multi-modal interaction (speech and gesture recognition) automated context tracking, dialog management and cognitive modeling.
–– *Advanced Visualization:* Developed new displays of military forces that improve Situational Awareness by from 27 percent to 86 percent of perfect awareness.
–– *Collaborative planning:* Developed radical new approach to collaboration that improves Common Situational Understanding from 27 percent to 92 percent perfect team understanding.
–– *Collaborative Execution:* Developed new collaborative interaction paradigm that enables parallel monitoring and execution.

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  - –– *Cognitive Modeling:* refined methodology for cognitive modeling of commanders' internal models of pattern recognition, information filtering, and force monitoring.
  - –– *Multi-Modal Interaction:* Continued development on multi-level input hierarchy that combines multiple speech and gesture recognizers. Experiments show improvements of recognition from 80 percent to 95 percent accurate.
  - –– *Dialog Management:* Demonstrated interactive dialog capabilities allowing commanders to query system by visual attribute.
  - –– *Automated context tracking*: Encoded the mental models captured in the CPOF commander's dialog system, and developed technologies for isolating and tracking cues for indexing the CPOF commander's dialog system.
- – Completed the first series of limited objective experiments (LOEs).
- – Instituted quarterly CPOF integration experiments to provide a venue for demonstration and assessment of new technologies.
- – Initiated the integration environment identified technology components for future inclusion into a mobile, distributed Battle Board system.
- – Encoded cognitive visualization principles into a knowledge base; developed tools for extracting and using visualization principles.

- Airborne Communications Node (ACN). ($ 30.169 Million)
  - – Down selected two teams for technology enabling payload architecture and development. This architecture will be targeted to operate within the stringent environment of the unmanned aerial vehicles, thereby stressing the packaging technology required to meet the form, fit and function. The payload architecture is modular and scalable, enabling subsets of the full functionality to be transferred to other SWAP-limited platforms.

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

- Dynamic Database (DDB). ($ 5.100 Million)
  - – Complete 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).
  - – Complete 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.

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- Complete initial capability for object discovery of large numbers of tactically significant ground targets (moving and stationary) over a brigade size area. This capability is achieved by an All-source Track and Identification Fusion (ATIF) algorithm, which automatically builds and maintains position, kinematic and ID features. ATIF unique capability to track targets through multiple move-stop-move cycles will be demonstrated.
- Demonstrate an initial capability to derive force relationships among objects using the Force Level Change Detection (FLCD) algorithm.
- Demonstrate an interactive DDB system-level capability that performs multi-sensor object level fusion using a Kosovo-like data set. All DDB components will be integrated with the High Performance Data Server to show the ability to perform multi-INT change detection to extract objects in clutter, track objects through move-stop-move cycles and determine force relationships.
- Conduct proof of concept experiments integrating components of DDB and AIM technology in a control theoretic framework. Experimentation will deal with management of sensor collections to meet information needs derived from DDB (e.g., ATIF and supporting fusion algorithms) to reduce uncertainty and ambiguity about objects. The result is a net improvement in the tracking and identification of objects. This technology will transition to the Dynamic Tactical Targeting (DTT) program.

• Command Post of the Future (CPOF). ($ 18.033 Million)
  - Continue 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.
  - Integrate and test new versions of the technology components in a series of simulation-based decision experiments.
  - Integrate the most effective technology into a complete CPOF commander's dialog system for an end-to-end demonstration in a simulated joint exercise.
  - Begin preparations for an operational demonstration of the CPOF commander's dialog system in a joint field exercise in FY 2002.

• Airborne Communications Node (ACN). ($ 27.512 Million)
  - Complete development of critical technologies.
  - Verify the critical technologies at the component level.
  - Mature the ACN system architecture to a preliminary design.
  - Conduct laboratory demonstration of critical subsystems.
  - Initiate development of signal processing algorithms to exploit ACN technologies for situational awareness and RF mapping.

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- Conduct "rooftop" measurements to validate situational awareness concepts.

(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.

- Symbiotic Communications. ($ 21.396 Million)
  - Complete ground experiments for signal and terrain scatter characterization.
  - Complete initial development of range compression algorithms.
  - Complete system analyses and trade studies.
  - Complete 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.

- Command Post of the Future (CPOF). ($ 4.676 Million)
  - Complete the final experiments in cognitive principals of visualization, multi-modal interaction, dialog management and command decision-making.
  - Complete technology development of CPOF component technologies of dynamic visualization, multi-modal interfaces and dialog management.
  - Integrate final component technologies and knowledge bases into the final prototype commander's dialog system; qualify system capabilities.
  - Participate in an advanced warfighting experiment using the CPOF commander's dialog system as the primary command interface of the brigade and battalion level.

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- Transition and integrate the CPOF commander's dialog system into the Global Command and Control System (GCCS), the DARPA/Army Future Combat System (FCS) and the Army's Agile Commander testbed.

- Next Generation (XG). ($ 4.000 Million)
  - Initiate CONUS and OCONUS Spectrum Usage Analysis.
    --Military Bands during Force Exercises.
    --Civilian Band ussage in a variety of locales (urban and rural settings).
  - Award Initial technology and systems contracts.
  - Conduct Initial Design Reviews.

- 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.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Airborne Communications Node:	
Sep 01	System performance review and simulation test results. TRL 4 laboratory demonstration.
Jan 02	System design review incorporating integration plan and physical architecture allocation.
Sep 02	Critical Design Review and TRL 5 laboratory demonstration.

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Command Post Of The Future:

Sep 01	CPOF Comprehensive Experiment Two to run at Fort Hood in warfighting experiment.
Sep 02	Demonstrate Course of Action (COA) level analysis within major Army exercises (e.g., Advanced Warfighter Experiment - AWE).

Symbiotic Communications:

Jul 01	Complete roof top ground experiments.
May 02	Complete terrain scatter studies.
Jun 02	Demonstrate range compression processing.
Apr 03	Complete early flight test.
Jun 03	Demonstrate SAR and DTED level three processing.
Aug 03	Preliminary Design Review for airborne system.

Next Generation (XG):

Nov 02	Initiate spectrum analysis research.
Sep 02	Initial system design, densing, dynamic waveform, sense and adapt technology development contract awards.
Feb 02	Analyze and measure spectrum usage in urban, open and forested environments.

Advanced Speech Encoding:

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 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	176.843	139.858	203.095	178.715	217.400	226.600	234.900	239.900	Continuing	Continuing
Guidance Technology SGT-01	18.069	20.844	30.605	21.964	26.515	29.568	29.568	29.568	Continuing	Continuing
Aerospace Surveillance Technology SGT-02	41.425	22.466	22.338	43.232	70.550	80.000	89.300	89.300	Continuing	Continuing
Air Defense Initiative SGT-03	35.884	21.941	32.667	10.000	12.750	14.200	23.200	28.200	Continuing	Continuing
Sensors and Exploitation Systems SGT-04	81.465	74.607	117.485	103.519	107.585	102.832	92.832	92.832	Continuing	Continuing

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

(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, high performance computing and low cost micro-electronics technologies.

(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.

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(U) The objective of the Sensors and Exploitation Systems project is to provide the warrior with situational awareness and battlefield dominance by developing key sensor technologies; provide near-real-time semi-automatic exploitation of wide-area moderate resolution imagery data; provide real-time and accurate battlefield assessment and semi-automated precise and reliable target recognition and targeting of critical moving targets.

(U) Program Change Summary: (*In Millions*)	**FY2000**	**FY 2001**	**FY 2002**
Previous President's Budget	177.598	182.225	203.424
Current Budget	176.843	139.858	203.095

(U) Change Summary Explanation:

FY 2000	Decrease reflects minor program repricing and SBIR reprogramming.
FY 2001	Decrease reflects net effect of congressional program reductions, congressional add for Large Millimeter Telescope, Section 8086 reduction and government-wide rescission.
FY 2002	Decrease reflects net effect of Discover II program termination, offset by planned expansions in the FOPEN Radar, and the Low Cost Cruise Missile Defense program, and initiation of an Extremely Large Space Antenna Study.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Guidance Technology SGT-01	18.069	20.844	30.605	21.964	26.515	29.568	29.568	29.568	Continuing	Continuing

(U) Mission Description:

(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. The Global Positioning System (GPS) Guidance Package (GGP) technologies funded in this project are applicable for both new or retrofit guidance/navigation packages for a variety of airborne platforms, ground vehicles, surface-to-surface standoff weapons and air-to-surface weapons. Additional thrusts are also included in this project to increase the ability of 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 (Advanced Tactical Targeting Technology Program).

(U) GGP tightly integrates a miniature GPS receiver and an all-solid state, low cost, navigation-grade, interferometric fiber optic gyroscope (IFOG) based miniature inertial measurement unit (MIMU) with an advanced navigation computer into a low cost ($15,000), precision navigation system. GGP Phase I addressed the technology issues involved in: (1) miniaturizing navigation grade inertial measurement units (IMUs) into a compact, manufacturable configuration; and (2) developing a multi-channel-on-chip, high dynamics GPS receiver. A Memorandum of Agreement (MOA) has been signed and implemented to demonstrate a Phase 1 unit on an Army Fire Support Team Vehicle (FIST-V). Successful demonstrations were conducted at Redstone Arsenal in June 1995 using a M981 FIST-V. Successful demonstrations also were conducted on an F/A-18. These tests assessed the performance of tightly coupled systems in high dynamics and validated Phase 1 design scenarios. GGP Phase 2 requirements place more stressing demands on performance of MIMU components and call for further reductions in size, power and weight.

(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

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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 will meet three key challenges. First, it will demonstrate non-Keplerian orbit predictions of the APL and show 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.

(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 and perform INS simulations of the modeled sensors. 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.

(U) The Advanced Tactical Targeting Technology (AT3) program will demonstrate a passive tactical targeting system for the lethal suppression of enemy air defenses (SEAD). The targeting system must negate emitter shutdown tactics now employed to defeat 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 radios with advanced network management and signal processing. Additionally, to achieve the necessary wide deployment, AT3 self-contained collection packages must impose negligible burden on their airborne hosts and be available at affordable prices. 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

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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 US 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 phenomonological measurements and develop countermeasures and target classification/identification techniques; (2) develop critical 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) <u>Program Accomplishments and Plans:</u>

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

- GPS Guidance Package (GGP) Global Positioning Experiments (GPX). ($ 3.621 Million)
  - Completed integration of GGP and field demonstrations.
  - Demonstrated ability of airborne pseudolites to provide high quality navigation data to GPS users during jamming.
  - Conducted laboratory demonstration of adaptive signal processing and digital beamformer for pseudolite anti-jam capability.

- Microelectromechanical Sensor Inertial Navigation System (MEMS INS). ($ 7.042 Million)
  - Began MEMS INS integration with navigation software to demonstrate IMU operation.

- Advanced Tactical Targeting Technology. ($ 7.406 Million)
  - Completed Advanced Tactical Targeting critical design and began fabrication.

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

- Global Positioning Experiments (GPX). ($ 3.796 Million)

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- Complete development and evaluation of elements of the pseudolite network.
- Initiate integrated demonstration using a single airborne pseudolite with integrated digital adaptive beamforming antenna.

• Microelectromechanical Sensor Inertial Navigation System (MEMS INS). ($ 5.402 Million)
- Deliver MEMS inertial measurement unit to the Government.

• Advanced Tactical Targeting Technology. ($ 11.646 Million)
- Complete fabrication and ground tests.
- Initiate advanced algorithm development.
- Complete study of EO/IR SAM fire control targeting.

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

• Global Positioning Experiments (GPX). ($ 8.043 Million)
- Complete captive carry weapon demonstration in a GPS jamming environment.
- Initiate fabrication of multiple airborne pseudolites.

• Microelectromechanical Sensor Inertial Navigation System (MEMS INS). ($ 1.880 Million)
- Complete field demonstration of MEMS INS navigation capabilities.

• Advanced Tactical Targeting Technology. ($ 9.725 Million)
- Conduct experimental flight tests and real-time multi-ship demonstrations.

• MEDUSA. ($ 10.957 Million)
- Develop and evaluate MEDUSA countermeasure and classification techniques and conduct phenomonological measurements.
- Initiate critical component technology development.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Sensor and Guidance Technology PE 0603762E, Project SGT-01

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

- Not Applicable.

(U) **Schedule Profile:**

Plan	Milestones
Jun 01	Complete GPX evaluation of pseudolite elements.
Jul 01	Deliver GGP units to the Government (second source).
Nov 01	Complete AT3 ground tests.
Feb 02	Complete laboratory demonstration of MEMS INS operations.
Jun 02	Complete field test/demonstration of MEMS IMU.
Jul 02	Demonstrate GPX airborne pseudolite operation with captive carry weapons.
Sep 02	Complete AT3 real-time flight tests.
Jun 03	Demonstrate in GPX integrated pseudolite system with live fire weapons in jamming environments.
Aug 03	Complete AT3 data analysis and field demonstrations.
Sep 03	Complete MEDUSA measurements database and breadboard system.

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APPROPRIATION/BUDGET ACTIVITY	R-1 ITEM NOMENCLATURE
RDT&E, Defense-wide BA3 Advanced Technology Development	Sensor and Guidance Technology PE 0603762E, Project SGT-02

COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Aerospace Surveillance Technology SGT-02	41.425	22.466	22.338	43.232	70.550	80.000	89.300	89.300	Continuing	Continuing

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

(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 architecture can be exploited for other missions, with the net effect of substantially enhancing U.S. situational awareness and combat identification advantages.

(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 program (CUGF) 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. The program has been expanded to include development and demonstration of a tactical missile that would have the ability to attack UGFs, the TACM-P system.

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(U) 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 high-availability, all-weather, survivable and short response time means to destroy hard and deeply-buried targets. The TACM-P ACTD has been endorsed by three Commanders in Chief (CINCs) to solve urgent needs within their theaters. U.S. Pacific Command is the operational sponsor.

(U) The RotoSAR program will develop revolutionary sensing capability by installing a receive antenna into the rotor blades of a surveillance or attack helicopter, either manned (e.g. Comanche, Apache), or unmanned (DARPA's hummingbird). The dynamics of helicopter blades enables a larger synthetic aperture, allowing improved ground moving target detection, particularly at low frequencies, such as required for foliage penetration. Under this program, techniques will be developed to compensate for blade motion in SAR/GMTI post-processing, transmit high bandwidth signals from a conformal antenna on the fuselage, and integrate the electronic receive antenna components with the (conductive) structural blade materials in a low loss and affordable manner. RotoSAR will be demonstrated on a tower mounted surrogate platform prior to insertion on a rotocraft. The presence of RotoSAR on an unmanned surveillance rotorcraft will provide a radar capability for immediate support of the battlefield commander.

(U) The Space Surveillance program will develop and demonstrate an advanced imaging 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 purpose such as asteroid detection and other defense missions.

(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.

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APPROPRIATION/BUDGET ACTIVITY **Error! Reference source not found.** BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Sensor and Guidance Technology PE 0603762E, Project SGT-02

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Digital Radio Frequency (RF) Tags. ($ 8.351 Million)
  - Completed a Preliminary Design Review (PDR) for a digital RF Tag, system level trade study, and technology insertion plan; selected two approaches for continued development.
  - Initiated advanced development of data encoding and extraction algorithms.

- Adaptive Spectral Reconnaissance. ($ 3.978 Million)
  - Completed visible through near infrared (VNIR)/short wave infrared (SWIR) algorithm development, including implementation of new algorithms and hybrid fusion techniques.
  - Completed VNIR/SWIR data collection, analysis and validation activities, including collections at Fort A.P. Hill and Aberdeen Proving Grounds.
  - Completed validation of end-to-end VNIR/SWIR spectral model including real/synthetic imagery generation, atmospheric/path radiance components, sensor models, platform dynamics and algorithm segments.
  - Completed spectral target and background signature database; released for distribution.

- Discoverer II. ($ 13.635 Million)
  - Completed Phase I satellite design efforts with two system integration (SI) contractor teams. Successfully completed second Interim Evaluation Review (IER) and IER-3 culminating in preliminary designs for demonstration satellites.
  - Completed mission utility analyses and concept of operations studies.
  - Built and tested sub-scale radar antenna designs, advanced signal processors and exploitation software.
  - Flew radar payload simulator on airborne asset; collected and analyzed data.

- Novel Antennas. ($ 1.497 Million)
  - Initiated analysis of next generation geolocation techniques technology for ground based communications exploitation.

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- Counter-Underground Facilities. ($ 10.464 Million)
  - Initiated robust modeling of passive acoustic-seismic-electromagnetic (PASEM) effluent signatures and backgrounds.
  - Initiated planning for field measurements to verify phenomenology, validate models and explore sensor deployment concepts.
  - Developed engineering descriptions of operational sites and their surrounding environments to support model validation and evaluation of system concepts within operational context.
  - Initiated active seismic characterization and battle damage assessment models and field experiments.
  - Initiated electromagnetic sensor technology development activities.

- Underground Facilities Detection. ($ 1.500 Million)
  - Initiated and evaluated acoustic and seismic technologies to improve underground facilities detection capabilities.

- Large Millimeter Telescope. ($ 2.000 Million)
  - Completed critical system design review.
  - Completed First Article Antenna Surface Panel.
  - Completed 3 mm receiver and conducted Bolometer test using CalTech telescope.

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

- Digital Radio Frequency (RF) Tags. ($ 6.575 Million)
  - Complete critical design review (CDR) for digital RF tag.
  - Conduct component risk reduction tests on brassboard system.

- Counter-Underground Facilities. ($ 11.891 Million)
  - Complete passive acoustic, seismic, electromagnetic (PASEM), and effluents modeling of signatures and backgrounds.
  - Initiate model validation experiments.
  - Initiate design for prototype PASEM demonstration system.
  - Develop and evaluate interface requirements definition and initiate hardware/software design for the Tactical Missile – Penetrator (TACM-P).

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- Large Millimeter Telescope. ($ 4.000 Million)
  - Complete detector/pointing system baseline controls.

(U) FY 2002 Plans:

- Digital Radio Frequency (RF) Tags. ($ 4.946 Million)
  - Complete tag prototype units.
  - Conduct laboratory device testing and characterization.

- Counter-Underground Facilities. ($ 8.446 Million)
  - Complete model validation for seismic, acoustic, electromagnetic and effluent signatures and backgrounds.
  - Complete passive acoustic, seismic, electromagnetic (PASEM), demonstration system design and fabrication.
  - Complete hardware/software design and initiate missile re-entry body system tests of the Tactical Missile – Penetrator (TACM-P).
  - Continue to develop and evaluate interface requirements definition and initiate hardware/software design for the Tactical Missile – Penetrator (TACM-P)

- RotoSAR. ($ 5.000 Million)
  - Perform analysis of post-processing requirements for blade motion compensation.
  - Identify candidate platform for installation and initiate system concept development.
  - Begin antenna module development.
  - Perform electromagnetic modeling of antenna/airframe interaction.
  - Develop software for synthetic aperture radar/ground moving target indicator (SAR/GMTI) from moving blades.
  - Conduct tower based demonstration of rotating blade concept from a signal processing perspective (non-real time).
  - Demonstrate, and quantify performance of, ultra high frequency (UHF) moving target indicator (MTI) from slow platforms using truck mounted UHF arrays.
  - Build and test a field deployable K-band rotosar surrogate, and demonstrate clutter mitigation techniques.

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- Space Surveillance ($ 3.946 Million)
  - Complete telescope design.
  - Complete focal plane design.

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

Adaptive Spectral Reconnaissance:

Source	FY 2000	FY 2001	FY 2002
Army	4.000	1.900	0.000

Discoverer II:

Source	FY 2000	FY 2001	FY 2002
NRO	13.330	0.000	0.000

Tactical Missile – Penetrator (TACM-P):

Source	FY 2000	FY 2001	FY 2002
OSD/ASCE PE 0603750D8Z	0.000	4.300	6.600
Air Force	13.170	0.000	0.000

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

<u>Plan</u>	<u>Milestones</u>
Digital Radio Frequency (RF) Tags:	
Oct 01	Final design review complete (FDR) for digital RF tag prototype.
June 02	Prototype RF tag component hardware fabrication and testing complete.
Counter-Underground Facilities:	
Sep 01	Complete interface requirements; conduct CDR for re-entry body; initiate hardware/software design for re-entry body.

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Nov 01	Complete model validation experiments.
Sep 02	Complete passive acoustic, seismic, electromagnetic (PASEM) demonstration system design and fabrication.
Sep 02	Complete hardware/software design for re-entry body. Conduct CDR and initiate flight hardware fabrication.

RotoSAR Program:

Apr 02	Complete post-processing requirements analysis.
May 02	Avionics preliminary design review.
Sep 02	Conduct tower based demonstrations.

Radar Technology:

Apr 02	Preliminary design review.
Aug 02	Fabricate pathfinder subscale radar.
Sep 02	Complete full-scale receiver exciter unit.
Oct 02	Subscale electronically scanned antenna (ESA) test.
Nov 02	Critical design review for full scale ESA.

Space Surveillance:

Mar 02	Focal plane design complete (preliminary design review).
Jul 02	Telescope design complete (critical design review).

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development					R-1 ITEM NOMENCLATURE Sensor and Guidance Technology PE 0603762E, Project SGT-03					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Air Defense Initiative SGT-03	35.884	21.941	32.667	10.000	12.750	14.200	23.200	28.200	Continuing	Continuing

(U) Mission Description:

(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 Synthetic Aperture Radar Electronic Counter-Countermeasures (SAR ECCM), Low-Cost Cruise Missile Defense (LCCMD), Global Eye, Microelectromechanical (MEM) antenna (MEM-tenna), Extremely Large Space Antenna Study and Polarized Infrared Imaging Seeker (PIRIS) programs.

(U) The SAR ECCM program will develop techniques to make U.S. Synthetic Aperture Radar (SAR) systems less vulnerable to intentional enemy jamming or deception. SAR systems have become one of the most widely used broad area surveillance systems. They are critically important to the development of battlespace awareness and their jamming and/or deception could seriously degrade U.S. warfighting capability. The SAR ECCM program will determine the military impact of various SAR jamming techniques and develop easily implemented countermeasures.

(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.

(U) The Global Eye program is developing the critical phased array antenna technologies and radar mode control concepts required for the introduction of multi-aperture, multi-function radar systems in UAVs. A UAV outfitted with this capability could provide lower cost (factor of ~20), continuous air and ground surveillance of low intensity areas such as no-fly zones and peacekeeping areas. Such capability could supplement traditional AWACS and E-2C and reduce the requirement to forward base large numbers of manned aircraft for these purposes. The key technologies to be used are: MEMS filters for simultaneous transmit and receive; polarization diversity, high efficiency solid-state transmitters;

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composite lightweight integrated antennas and advanced mode control/interleaving algorithms. Concepts will be explored which use common components to perform both the AEW mission (at the reduced ranges appropriate to this concept) and air-to-ground modes.

(U) The MEM-tenna program is developing ultra-low cost, lightweight phased array antenna technologies based on MEMS phase shifters and RF beam control through optical projection techniques. MEMS technology can produce phase shifters for phased array antennas that are a small fraction of the power consumption of conventional PIN-diode or GaAs field effect transistor (FET) phase shifters, while also having low insertion losses. Hard-wired beam steering control and RF manifolds are replaced by optical and RF space-fed configurations. Using these technologies, very large-scale electronically scanned arrays (ESAs) can be developed for multiple applications. Optically controlled phase shifter designs incorporating MEMS technology are being developed and these will be incorporated into a prototype ESA having 10,000 antenna elements, operating at X-band with potential application to airborne and surface-based missions.

(U) MEM-tenna and other ultra-low cost, lightweight technologies offer the potential for developing and deploying extremely large antennas in space. Antennas of 100 – 300 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 study will be conducted to assess and produce feasible and affordable candidate extremely large antenna designs capable of performing tactical sensing from space.

(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) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

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- SAR ECCM. ($ 8.064 Million)
  - Demonstrated a series of off-line image-based post-processing ECCM techniques.
  - Formally transitioned SAR ECCM algorithms to the Air Force Research Labs' Sensor Directorate for integration into the Joint STARS T-3 test platform and the Army's Common Ground Station.
  - Established problem awareness at key institutions (NGIC, NAIC and AC2ISRC) responsible for determining the Mission Need Statements (MNS) and Operational Requirements Documentation (ORD).
  - Introduced annual ECCM operational exercises into the Joint Expeditionary Force Exercise (JEFX).

- LCCMD. ($ 16.745 Million)
  - Upgraded Laser Radar (LADAR) seeker to eye-safe frequency and redesigned seeker to increase acquisition range.
  - Initiated laboratory characterization testing of upgraded LADAR seeker.
  - Initiated Micro Electro-Mechanical (MEMS) Electronically Scanned Array (ESA) radar seeker antenna subarray laboratory testing.
  - Initiated MEMS improvement program to address MEMS reliability problems identified in subarray testing.
  - Completed noise radar seeker flight system integration and initiated laboratory testing.
  - Designed noise radar seeker processor chips.

- Global Eye. ($ 3.131 Million)
  - Initiated prototype antenna and system concept designs.
  - Initiated mode control/interleaving algorithm development.
  - Initiated the design of MEMS-based filters required for the use of simultaneous transmit and receive (STAR) waveforms.

- MEM-tenna. ($ 7.944 Million)
  - Initiated design of a prototype ESA that will incorporate optically controlled X-band MEMS phase shifters, along with the design of the integrated phase shifter and optical controller modules.
  - Developed designs of MEMS X-band phase shifters and initiated prototype manufacturing to demonstrate the ability to achieve the cost and reliability goals.

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(U) **FY 2001 Plans:**

- LCCMD. ($ 12.473 Million)
  - Complete laboratory characterization testing of eye-safe LADAR seeker.
  - Design, fabricate and test improved RF MEMS capacitive and contact switches for use in MEMS antenna array.
  - Complete noise radar seeker China Lake field-testing.
  - Complete fabrication and testing of noise radar seeker correlator and Fast Fourier Transform (FFT) Integrated Circuit (IC) chips.

- Global Eye. ($ 3.275 Million)
  - Initiate the fabrication of MEMS-based filters to permit the use of simultaneous transmits and receive (STAR) waveforms.
  - Begin risk reduction phased array fabrication and tests.

- MEM-tenna. ($ 5.193 Million)
  - Evaluate of 100 phase shifters built by three contractors.
  - Begin manufacture of the 11,000 MEMS X-band phase shifters with optical controllers.
  - Develops array calibration techniques with both specific and general applicability.
  - Initiate MEMS lifetime and reliability program.

- Advanced Sensing Alternatives. ($ 1.000 Million)
  - Explore 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. ($ 15.000 Million)
  - Conduct real-time noise radar seeker processor demonstration using China Lake field test data.
  - Complete noise radar seeker final report.

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- 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 Engineering and Manufacturing Development (EMD) quality RF MEMS switches.

• Global Eye. ($ 2.000 Million)
  - Demonstrate continuous wave operation of sub-array.
  - Insert the MEMS filters into the prototype array and evaluate its ability to support multiple-mode operation.
  - Populate an active ESA with a sufficient number of modules and filters to demonstrate multi-mode radar compatibility with full STAR waveform transmit capability.

• MEM-tenna. ($ 3.667 Million)
  - Complete the fabrication of the 10,000 element space-fed array and perform proof-of-concept testing.
  - Evaluate remote array calibration techniques using sub-scale array.
  - Conduct experiments of alternative, novel and space-fed technologies.

• Extremely Large Space Antenna Study. ($ 11.000 Million)
  - Develop detailed conceptual designs of multiple antenna candidates.
  - Assess feasibility and affordability of designs.
  - Identify critical technologies and risk reduction requirements.

• PIRIS. ($ 1.000 Million)
  - Conduct field experiments to verify degree-of-polarization separation of targets and infrared countermeasures.
  - Conduct conceptual design of prototype-polarized seeker.

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

• Not Applicable.

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(U) Schedule Profile:

Plan	Milestones
LCCMD:	
Jun 01	Start noise radar seeker field test.
Oct 01	Start noise radar seeker real-time processor test.
Oct 02	Conduct MEMS ESA seeker critical design review.
Global Eye:	
Aug 01	Complete basic sub-array fabrication and begin testing.
Nov 01	MEMS filter insertion.
Mar 02	Begin population of active ESA for proof-of-concept demonstration.
Jun 02	Multiple-mode demonstration.
MEM-tenna:	
Jun 01	Complete MEMS lifetime and reliability study.
Aug 01	Begin production of 11,000 integrated MEMS phase shifter and optical controller modules.
Dec 01	Begin fabrication of sub-scale array.
Jun 02	Begin sub-scale array testing.
Aug 02	Conduct remote array calibration testing.
PIRIS:	
May 02	Complete degree-of-polarization field experiments.
Aug 02	Complete preliminary design for prototype.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Sensors and Exploitation Systems SGT-04	81.465	74.607	117.485	103.519	107.585	102.832	92.832	92.832	Continuing	Continuing

(U) Mission Description:

(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; Eyeball, a multispectral electro-optical (EO)/infrared (IR)/radar identification concept; Affordable Moving Surface Target Engagement (AMSTE); Real-Time Battle Damage Assessment (R/T BDA), Tactical Targeting Network Technologies (TTNT); Organic Ground Moving Target Identification (GMTI) Radar (OGR); Dynamic Tactical Targeting (DTT); Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER) and the Eyeball Program.

(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 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.

(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

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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 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 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 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 threat targets such as surface-to-air missile launchers, theater surface-to-surface missile launchers and multiple rocket launchers. R/T BDA will exploit organic and theater synthetic aperture radar sensors to assess effectiveness of munitions delivery and provide feedback to attack systems in mission, with a goal of providing weapon effectiveness metric 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,

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sensor-fuzed weapons, and similar weapons that typically provide less energetic effect on the target and are therefore more difficult to assess by traditional BDA techniques.

(U) 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. The Tactical Targeting Network Technologies (TTNT) program will develop, evaluate and demonstrate rapidly reconfigurable, affordable, robust, interoperable and evolvable communications technologies specifically to support this critical application class. Specifically, the program will develop and demonstrate a prototype distributed tactical network with the following features: reconfiguration in fractions of a second, wideband capacity on demand, near zero latency, transparent operation within existing links, and inexpensive enough to be ubiquitous. Technologies to be developed include wideband waveform underlays, and rapid network planning tools and advanced network simulations.

(U) The goal 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 3-5 km and personnel at ranges of 1-3 km with low false alarm rates. The concept is based on the use of separate transmitters and receivers, each of which is 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. 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.

(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 in ISR products by leveraging devices from the Digital Radio Frequency Tags (DraFT) program to develop multi-spectral transponders to conduct in-scene registration of all sensor data; 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 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

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information to shooters. The product of the DTT program will be a transportable testbed capable of demonstrating real time targeting of mobile TCTs in an operational 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) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Semi-Automated Imagery Intelligence Processing (SAIP) ACTD. ($ 5.385 Million)
  - Completed operational support to the Army and Air Force SAIP residual operational capability.

- Moving and Stationary Target Acquisition and Recognition (MSTAR). ($ 15.421 Million)
  - Demonstrated major improvements in ATR performance as a function of resolution.
  - Investigated recognition capabilities using RF returns without forming the imagery.
  - Established an integration and transition capability in the Real Time ATR Laboratory (R/T ATR Lab) for the purpose of developing MSTAR based "modules" that can be used to upgrade operational ATR systems such as SAIP.

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- Demonstrated the ability to operate the MSTAR system in near real time through the use of parallel super-computers in the R/T ATR Lab. Developed a toolkit of interactive exploitation tools, integrated with commercial technology, that provided operationally useful ATR capabilities to image analysts.
- Conducted an initial exploration of MSTAR model-based reasoning technology using SAR data in conjunction with 3-D Laser Radar (LADAR) data of ground targets.

• Airborne Video Surveillance (AVS). ($ 13.016 Million)
  - Integrated, demonstrated and evaluated the following technologies in the laboratory and in some limited field experiments: Activity Monitoring – monitored activities (e.g., soldier incursion into security zones, tactical and strategic vehicle movement) and developed activity-based indexes for tactical video data stores. Precision Video Registration – Demonstrated 2 to 10-meter absolute geolocation accuracy in 80 percent of mission imagery from multiple terrain types.

• Counter Camouflage, Concealment and Deception (CC&D). ($ 27.095 Million)
  - Completed hardware development and system integration.
  - Began conducting preliminary flight tests of the FOPEN SAR Manned Airborne Demonstrator on Army aircraft.
  - Focused the Multi-Sensor Exploitation Testbed (MSET) on the development of SAR and spectral MSI image feature fusion techniques to demonstrate the achievable performance gain in overall detection and false alarm rate with multimode systems. These capabilities can be utilized with the ATD/C algorithms to demonstrate and project Counter CC&D capabilities.
  - Performed a multispectral data collection using SAR and spectral sensors to assess fusion performance for targets in shallow hide.
  - Initiated concept development studies for FOPEN GMTI/ESM.
  - Conducted a moving target signature measurement experiment.
  - Performed a data collection experiment with an airborne UHF GMTI sensor.

• Affordable Moving Surface Target Engagement (AMSTE). ($ 15.163 Million)
  - Completed a weapon system trade study of "higher-order" error terms and initial precision fire control tracking experiments. The study products included an end-to-end operational system design, end-to-end concept of operations and system performance analysis.
  - Developed multi-sensor registration, association and tracking algorithms.

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- Conducted iterative experimentation using simulated and real multi-sensor GMTI data, confirming the theoretical predictions of less than 10 m targeting errors.

• Organic Ground Moving Target Identification Radar (OGR). ($ 5.385 Million)
- Completed the fabrication and initiated the evaluation of the brassboard proof-of-concept system.
- Conducted testing using both airborne and ground illuminators.
- Began planning for an experiment using an HDTV transmitter.
- Began planning for full scale testing and evaluation.
- Investigated the performance limitations when using non-rigid antenna structures for the receiver array. Modified to allow operation with an airborne illuminator.

(U) **FY 2001 Plans:**

• Counter Camouflage, Concealment and Deception (CC&D). ($ 18.831 Million)
- Complete FOPEN SAR preliminary flight test.
- Begin FOPEN SAR development flight test to gather data on targets and background algorithm training.
- Continue FOPEN GMTI/ESM data analysis and signal processor development to mitigate false alarms and clutter contamination.
- Complete SAR and spectral data fusion analysis.

• Affordable Moving Surface Target Engagement (AMSTE). ($ 35.665 Million)
- Design, develop and fabricate the initial field experiment system, including airborne sensors modified to support real-time fire control and a weapon data link.
- Conduct field experiments to evaluate the capability to perform precision fire control targeting against moving targets, culminating in an inert weapon drop.
- Evaluate data recorded during field experiments. Laboratory analyses will include investigation of various levels of sensor performance, use of a low-cost terminal guidance seeker and extrapolation to operational systems.

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- Explore advanced tactical data link technologies to enable rapidly reconfigurable, low latency, wideband modes to transparently operate on existing links. Conduct Link-16 network planning experiment with the Air Force at Nellis AFB.
- Develop 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.
- Develop advanced GMTI processing approaches to mitigate track contamination.

• Organic Ground Moving Target Identification Radar (OGR). ($ 7.679 Million)
  - Enhance capabilities of brass board system.
  - Conduct detailed experiments at multiple sites using bistatic modes with both airborne and ground based transmitters to characterize propagation effects, radar phenomenology and system accuracy.
  - Begin operational demonstrations.

• Eyeball. ($ 1.872 Million)
  - Conduct concept definition including phenomenology assessment, spatial-spectral-polarimetric trades, modeling and simulation, and experiment requirements definition.
  - Initiate the sensor testbed design and perform risk mitigation activities.
  - Link polarimetric model enhancements into the Spectropolarimetric Sensor Evaluator, develop new model elements and validate against measured data sets.

• Real-Time Battle Damage Assessment (R/T BDA). ($ 10.560 Million)
  - Initiate RF data collection efforts.
  - Investigate RF techniques to exploit change detection to identify weapons-effects signatures in synchronized pre- and post-strike SAR imagery; couple this signature assessment with real-time prediction of target functional degradation.
  - Initiate algorithm development to exploit thru-strike radar phase history data.
  - Conduct precision munition "pop-off" BDA sensor conceptual designs for a range of weapons.

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(U) **FY 2002 Plans:**

- Counter Camouflage, Concealment and Deception (CC&D). ($ 18.000 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.
  - Continue developing techniques for false alarm and clutter contamination mitigation.
  - Conduct millimeter wave FOPEN data collects and develop conceptual design.

- Affordable Moving Surface Target Engagement (AMSTE). ($ 39.563 Million)
  - Complete design, development and fabrication of an enhanced field experiment system to support evaluation of moving target engagement capabilities.
  - Conduct 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 will be focused on complex target densities, target dynamics, and enhanced bias estimation/removal approaches.
  - Demonstrate a full AMSTE weapons delivery capability in live weapons drops.
  - Integrate advanced target track maintenance techniques into the system to support field experiments.

- Organic Ground Moving Target Identification Radar (OGR). ($ 6.100 Million)
  - Complete phenomenological investigations.
  - Proceed with in-depth operational demonstrations.

- Eyeball. ($ 6.422 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). ($ 15.900 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). ($ 12.000 Million)
  - Complete studies, simulations and initial feasibility experiments.
  - Conduct risk reduction experiments for critical components.

- Dynamic Tactical Targeting (DTT). ($ 9.500 Million)
  - Demonstrate functionality of multi-spectral transponders; demonstrate automated registration algorithms for ISR and in-situ sensors.
  - Develop models for selected in-situ sensors.
  - Initiate fusion experiments of Intelligence, Surveillance and Reconnaissance (ISR) and in-situ sensors.
  - Demonstrate adaptive allocation of ISR sensor resources to enable: efficient search profiles, deployment of additional state change detectors, and track maintenance of objects/targets.
  - Develop interface definition of the transportable DTT Testbed to an operational system with Tactical Exploitation System (TES) functionality.

- 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.
  - Define high performance embedded computing architecture to enable rapid memory access, and develop radar design for advanced airborne sensor platforms supporting this architecture.
  - Initiate planning for advanced algorithms for real-time demonstration.
  - Initiate development for real-time software.

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(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Foliage Penetration (FOPEN)	
Sep 01	MSET re-host to SAIP residual for field demonstrations.
Nov 01	Verify FOPEN SAR automatic target detection and cueing.
Dec 02	Complete user evaluation of FOPEN SAR operational utility.
Affordable Moving Surface Target Engagement (AMSTE)	
Aug 01	Complete NTsim Link 16 terminal simulator.
Sep 01	AMSTE initial airborne precision fire control and engagement field demonstration.
Sep 01	Complete Link-16 Experiments.
Sep 02	AMSTE live weapons demonstration and track maintenance integrated field experiment.
Aug 03	AMSTE end-to-end system operational demonstration with BM/C3 integration and full threat dynamics.
Eyeball	
Jun 01	Complete Eyeball spatial-spectral-polarimetric architecture trades and target identification concept definition.
Oct 01	Complete Eyeball preliminary/experimental designs. Complete sensor limits report.
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.
Organic Ground Moving Target Identification (OGMTI)	
May 01	Test OGR in tropical forest environment.

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Aug 01 Test OGR deciduous forest in summer conditions.
Jan 02 Test OGR deciduous forest in winter conditions.
Jun 02 Demonstrate OGR operational utility.

Real-Time Battle Damage Assessment (R/T BDA)
May 01 Complete R/T BDA weapon-deployed sensor conceptual design.
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 R/T BDA experiment/demonstration design.

Tactical Targeting Network Technologies (TTNT)
Dec 01 Complete TTNT common tasks and distribute results to primes.
Sep 02 Down select the prime contractors to enter phase two of TTNT.

Dynamic Tactical Targeting (DTT)
Feb 02 Complete selection of appropriate in-situ sensors for the DTT program.
Apr 02 Complete preliminary design of the transportable DTT testbed.

KASSPER
Apr 02 Monostatic Radar Data Collection.
Aug 02 Real-Time Algorithm Preliminary Design Review.

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COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	21.845	27.937	41.497	31.896	45.700	57.500	60.200	72.600	Continuing	Continuing
Advanced Ship-Sensor Systems, MRN-02	21.845	27.937	41.497	31.896	45.700	57.500	60.200	72.600	Continuing	Continuing

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

(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), Water Hammer, Buoyant Cable Array Antenna (BCAA), Robust Passive Sonar (RPS), and Loki 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. In addition, the ULW program is developing approaches to undersea warfare that will revolutionize the ability to classify and identify underwater objects and improves search rates more than an order of magnitude greater than is possible with current techniques.

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(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 washover 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 ULW 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 Water Hammer program conducted concept development for a standoff mine neutralization system consisting of a phased array of shock tubes to generate, focus and transport to militarily important distances (tens of meters) a pressure pulse of sufficient energy to neutralize the threat.

(U) Specific sensor, payload, structural, materials, and propulsion concepts, generated in part under the Submarine Payloads and Sensors Program (PE 0603763E, Project MRN-02), will be investigated for implementation into Loki- a revolutionary new underwater fighter program. The Loki program is complementary to planned naval forces and is intended to develop and demonstrate the critical technologies needed to provide the U.S. with a lethal, stealthy, high-speed underwater fighter. The Loki program will provide the U.S. with an asymmetric operational advantage in the littoral regions analogous to those enjoyed by U.S. fighter aircraft in air combat. It will rely on advanced sensor systems to provide the pilot with immersive, highly automated, and robust situational awareness, a power and energy system capable of low speed, cruise and high-speed operations.

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

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

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- Undersea Littoral Warfare (ULW). ($ 16.189 Million)
  - Completed development of prototype NetSAT system.
  - Conducted NetSAT follow-on technical demonstration, improved endgame coordination with existing systems for final target updates to improve overall effectiveness.
  - Conducted mine target strength and target structure studies in support of advanced classification techniques for Synthetic Aperture Sonar (SAS) systems; compared predictive models with laboratory measurements.
  - Assessed Robust Passive Sonar (RPS) performance improvements in passive sonar from exploitation of external information (overhead surveillance and acoustic monitors).
  - Commenced RPS development of adaptive processing algorithms for advanced surface shipping interference rejection.

- Buoyant Cable Array Antenna (BCAA). ($ 4.931 Million)
  - Conducted component technology risk reduction and maturation.
  - Initiated design and development of a full duplex (transmit/receive) submarine BCAA prototype antenna.
  - Completed system definition for prototype; conducted preliminary design review.

- Water Hammer. ($ 0.725 Million)
  - Completed and tested 4x4 source array.
  - Validated nonlinear numerical model from test results

(U) **FY 2001 Plans:**

- Undersea Littoral Warfare (ULW). ($ 19.496 Million)
  - Conduct final NetSAT operational demonstration.
  - Continue development of adaptive processing algorithms for advanced surface shipping interference rejection.
  - Commence development of noise-rejection algorithms exploiting external information.
  - Conduct preliminary Robust Passive Sonar (RPS) performance assessment using existing datasets.
  - Create baseline integrated RPS interference rejection processing stream.

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- Buoyant Cable Array Antenna (BCAA). ($ 5.341 Million)
  - Complete algorithm and software development for space-time adaptive communications link processor.
  - Complete design of BCAA prototype antenna; conduct critical design review.
  - Fabricate BCAA prototype antenna; commence integration with submarine deployment and retrieval systems.

- Future Submarine Payloads Program. ($ 3.100 Million)
  - Conduct structural, material, and architectural trade studies to allow storage and launch of existing payloads in an underwater environment.
  - Commence conceptual designs for the underwater launch and recovery of future payloads.
  - Transfer findings for use by the Loki program in FY 2002.

(U) FY 2002 Plans:

- Buoyant Cable Array Antenna (BCAA). ($ 7.733 Million)
  - Complete integration of BCAA prototype antenna with submarine deployment and retrieval systems.
  - Complete at-sea technical validation of BCAA prototype from surface platform.
  - Conduct at-sea operational demonstration of BCAA prototype from submarine.
  - Transition BCAA technology to Navy for follow-on development.

- Robust Passive Sonar (RPS). ($ 14.653 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.

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- Loki Program. ($ 19.111 Million)
  - Initiate structural, material and architectural trade studies, including:
    - Interface descriptions and explorations,
    - Hydrodynamic performance modeling, and
    - System structural materials explorations.
  - Component technology development.
  - Assess impact of concept on existing platforms including launch and recovery.
  - Initiate sensor guidance and control design studies.
    - Simulation modeling of high agility, full speed control authority.
    - Conduct investigations into novel communications and sensing modalities.
    - Commence development of autonomous control systems; assess performance in an adverse environment without a priori training.
    - Component technology development for integrated electronics and software systems.
  - Begin investigations into advanced propulsion systems.
    - Demonstrate submergence performance of vortex combustors.
    - Demonstrate performance rates for advanced propulsion system.
  - Conduct concept of operations and military utility studies.

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

	FY2000	FY 2001	FY 2002
Previous President's Budget	21.681	30.304	38.257
Current Budget	21.845	27.937	41.497

(U) **Change Summary Explanation:**

FY 2000	Decrease reflects minor repricing and SBIR reprogramming.
FY 2001	Decrease reflects the Section 8086 reduction, government-wide rescission and deferral of Friction Drag Reduction efforts based on results of the 6.1 Drag Reduction efforts that led to establishment of a 6. 2 program in

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PE 0602702E, Project TT-03. The funding decrease associated with this deferral was partially offset by cost increases in the Buoyant Cable Array Antenna and Undersea Littoral Warfare programs.

FY 2002 Increase reflects additional funds for the Loki program, which was also funded by reapplication of related efforts from Undersea Littoral Warfare program, Future Submarine Payloads program and Advanced Maritime Propulsion.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Undersea Littoral Warfare (ULW):	
Jun 01	Conduct sensor-to-shooter operational demonstration including surveillance detection, handoff, targeting and attack in a countermeasure environment.
Dec 01	Complete SAS classification performance assessment.
Apr 02	Conduct SAS data collection exercises.
Buoyant Cable Array Antenna (BCAA):	
Nov 01	BCAA multi-element antenna prototype system complete.
Apr 02	Conduct surface ship system test.
Sep 02	Conduct submarine system demonstration.
Robust Passive Sonar (RPS):	
Sep 01	Baseline interference rejection processing stream for passive sonar created.
Mar 02	Complete Initial data collection field exercise.
Apr 03	Demonstrate non real-time end-to-end system processing.

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Loki Program:

Jul 02	Issue initial baseline report.
Sep 02	Hydrodynamics performance testing.
Sep 02	Report on advanced propulsion experiments.
Oct 02	Report on advanced sensing guidance and control modality investigations.
Jan 03	Conduct Initial Design Review for prototype system.
Jul 03	Issue technical design report for critical navigation and communications systems.
Sep 03	Sensor, guidance and control systems testing.
Sep 03	Advanced propulsion endurance and economy testing.
Sep 03	Personnel pod qualification.

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COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	94.578	129.025	153.067	182.100	148.500	113.600	119.300	120.600	Continuing	Continuing
Rapid Strike Force Technology LNW-01	51.983	31.993	19.992	21.500	26.600	32.000	37.000	37.000	Continuing	Continuing
Small Unit Operations LNW-02	42.595	36.032	43.075	38.600	59.000	66.600	82.300	83.600	Continuing	Continuing
Future Combat Systems LNW-03	0.000	61.000	90.000	122.000	62.900	15.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(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 Rapid Strike Force Technology project is developing the technologies necessary for highly mobile, covert transportation and information gathering systems to enhance U.S. early-entry capabilities. 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; 4) the pre-cursor efforts of the Future Ground Combat System program that will explore and develop technologies to be used by tactical commanders in situational awareness, communications and control; and 5) the Metal Storm program that will develop a system to pack, transport and fire at variable sequence rates.

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(U) The goal of the Small Unit Operations project is to develop critical technologies that will enable dispersed units to effectively perform warfighting operations traditionally requiring massed forces. Technology development efforts will focus on a comprehensive awareness capability that provides real-time, essential information for small units and individual warfighters; wireless communication technologies to permit exchange of voice, digital and video data with other systems; geolocation technologies that provide navigation information in built-up, forested and mountainous environments; internetted tactical surveillance and targeting sensors to complement information requirements not satisfied by national, theater and component sensor programs; automated ultra-miniature imaging and non-imaging sensors and the use of robotic technology to impact operations in urban areas.

(U) The Future Combat Systems project goal is to develop an effective, light-weight suite of inhabited and uninhabited ground based systems that strike an optimal balance among critical performance factors, including ground platform strategic, operational and tactical mobility, lethality, survivability and sustainability. Efforts will focus on creating a multi-functional, multi-mission, re-configurable group of systems that maximize joint interoperability, strategic transportability and commonality of mission roles. These efforts will concentrate in six areas: robotic perception; unmanned ground combat vehicles; maneuver command, control and communication; beyond line of sight fires; organic all weather air vehicles; and organic all weather targeting. Support programs will develop rapid response and lethality packages requiring fewer personnel, decreased logistical support and lower life-cycle costs while increasing survivability.

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

	FY2000	**FY 2001**	**FY 2002**
Previous President's Budget	96.320	134.249	157.667
Current Budget	94.578	129.025	153.067

(U) Change Summary Explanation:

FY 2000 Decrease reflects SBIR reprogramming and minor program repricings.

FY 2001 Decrease reflects the Section 8086 reduction, the government-wide rescission and minor program repricing.

FY 2002 Decrease reflects the phase down of Tactical Sensors and Situational Awareness System efforts and completion of Advanced Sensing Technology work.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Rapid Strike Force Technology LNW-01	51.983	31.993	19.992	21.500	26.600	32.000	37.000	37.000	Continuing	Continuing

(U) Mission Description:

(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; Metal Storm (MS); Combat Hybrid Power Systems (CHPS); and the pre-cursor efforts of the Future Ground Combat System (FCS). 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) ATD 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 Solar Blind Detectors program (formerly titled "Vehicle Self-Protection") will develop 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) The Metal Storm (MS) program will develop a unique 100 percent solid state system for tightly packing, storing, transporting and firing projectiles in multiple tubes with high or low pressures, in an electronically infinitely variable sequence rate with applications to small arms and crew served weapons. The program facilitates current U.S. force reduction and restructuring policies while increasing firepower. The program will demonstrate revolutions in weapon design and application that will far exceed the effectiveness and versatility of existing small arms and large munitions weaponry, and will primarily focus on developing, fabricating and testing two sniper rifle prototypes for Special Operations Forces (SOF) use. The design will incorporate a multi-barrel configuration allowing instant access to a variety of projectiles. Studies will be conducted to optimize propellants and projectiles; to examine electronic keying, silencing and underwater operations; and to investigate the physics of scaling from a small caliber, low-pressure design to a large caliber (40 and 81mm), modest barrel pressure (~60,000 psi) design. Through a Project Arrangement under the Deutsch Ayers Agreement between the U.S. and Australia, the Defence Science and Technology Office (DSTO) will perform work in the areas of scaling, modeling and simulation, and small arms live fire testing.

(U) The Combat Hybrid Power System (CHPS) program developed enabling technologies and conducted demonstrations of an integrated hybrid electric power system to provide power and energy management for all of the electric subsystems throughout future combat vehicles. Hybrid

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electric power is an essential enabling technology for future combat vehicles given the number of electrically powered subsystems planned for implementation. The program transitioned to the U.S. Army at the beginning of FY 2001 and the technologies developed will play a key role in the Future Combat System (FCS) program.

(U) The Future Combat Systems (FCS) program, an out-growth of the Mobile Tactical Operations Center, 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 integrated command and control capabilities with unsurpassed situational understanding for all levels of commanders. The FCS program is funded in project LNW-03, Future Combat Systems, within this Program Element (0603764E) in FY 2001 and subsequent fiscal years.

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

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

- Combat Hybrid Power Systems (CHPS). ($ 10.074 Million) [Future Combat Systems – related = $10.074 million]
  - Installed engine and thermal management system in the Systems Integration Laboratory (SIL) and operated the system with various combinations of engine, flywheel and battery to determine performance baselines for notional concept vehicle (15 tons).
  - Completed advanced, high-risk hybrid electric power system components, including the high energy/high power CHPS Lithium Ion Battery and Silicon Carbide DC/DC converter.
  - Investigated alternative power system component technologies, including Ultra capacitors and in-wheel hub motors.
  - Initiated testing and evaluation of integrated hybrid electric power system and subsystems.
  - Developed a plan to systemically investigate and qualify benefits of hybrid electric power for future combat vehicles using SIL and hardware-in-the-loop virtual prototype.
  - Developed a coordinated research plan for continued effective utilization of CHPS SIL and virtual prototypes.
  - Completed transition of CHPS program to U.S. Army Tank-Automotive and Armaments Command (TACOM).

- Reconnaissance, Surveillance and Targeting Vehicle (RST-V). ($ 10.651 Million)
  - Performed wheel motor qualification tests.
  - Rolled out vehicles 1 and 2.

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- Tactical Mobile Robotics (TMR). ($ 15.699 Million)
  - Initiated development of fully functional tactical robotic prototypes.
  - Integrated enabling technologies into functional platforms.
  - Refined demonstration and transition plans commensurate with success in system design and multi-platform collaboration.
  - Conducted technical experiments in machine perception and autonomous navigation of indoor cluttered environments.

- Solar Blind Detectors Program. ($ 5.679 Million)
  - Demonstrated low defect epitaxial material compatible for photo detectors with high sensitivity operating in the solar-blind region of the spectrum (260-280 nm).

- Future Combat Systems (FCS). ($ 6.896 Million)
  - Awarded agreements to four industrial teams for FCS concept development.
  - Began formulation of force level concepts.
  - Initiated development of standard threat scenarios.
  - Initiated Integrated Development Environment (IDE).
  - Initiated independent validation, verification and accreditation effort.
  - Concept development teams performed initial technology surveys (DoD-wide activities) and initial force capabilities.

- Advanced Concepts Evaluation. ($ 2.984 Million)
  - Conducted technology assessment and feasibility testing of advanced rapid strike force concepts including precision guided munitions, force-on-force modeling, counter situational awareness, covert autonomous sensors and future unmanned vehicle systems.
  - Conducted studies to optimize the Metal Storm concept, research propellants and projectiles, and developed approaches to enhance accuracy. Established international agreement between the U.S. and Australia.

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

- Reconnaissance, Surveillance and Targeting Vehicle (RST-V). ($ 7.334 Million)
  - Participate in U.S. Marine Corps (USMC) Advanced Warfighting Experiment.

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– Integrate and demonstrate Survivability Suite.

- Tactical Mobile Robotics (TMR). ($ 10.432 Million)
  - Complete initial prototype development.
  - Complete initial design of Human Robot Interface for multi-robot control, heterogeneous platform collaboration and marsupial operations.
  - Initiate tactical experiment plan with fully functional platforms to determine operational value baseline.
  - Refine collective experimentation plan.

- Solar Blind Detectors Program. ($ 4.736 Million)
  - Demonstrate solar-blind detector array with 256 x 256 pixels.

- Metal Storm (MS). ($ 9.491 Million)
  - Finalize designs for main sniper rifle and targeting and electronic subsystems.
  - Perform scaling analysis of Metal Storm technology to larger calibers.

(U) **FY 2002 Plans:**

- Reconnaissance, Surveillance and Targeting Vehicle (RST-V). ($ 3.242 Million)
  - Demonstrate V-22 compatibility.
  - Complete RST/ C^4I test.
  - Deliver vehicles 1, 2, 3, and 4.
  - Deliver final report.

- Metal Storm (MS). ($ 10.017 Million)
  - Demonstrate a single-barrel model of the electronic sniper rifle.
  - Initiate design and tradeoff analysis of a multi-barrel model.
  - Conduct Critical Design Review of the multi-barrel model.

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- Demonstrate preliminary design firing.
- Conduct technology assessment and feasibility testing of smart projectile enhancements to Metal Storm for protection against Anti-Ship Cruise Missiles and point defense of high-value airborne and ground assets.

- Tactical Mobile Robotics (TMR). ($ 6.733 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.
  - Initiate transition to military departments.

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

	FY2000	FY2001	FY2002	FY2003
Reconnaissance, Surveillance and Targeting Vehicle (RST-V) PE 0603640M Marine Corps Advanced Technology Demonstration	2.150	2.750	2.990	1.000
Combat Hybrid Power System (CHPS)				
PE 0603005A Combat Vehicle and Automotive Advanced Tech	2.000	4.700	0.000	0.000
Future Combat Systems				
PE 0602601A Combat Vehicle and Automotive Technology	6.586	0.000	0.000	0.000
PE 0603005A Combat Vehicle and Automotive Advanced Technology (FCS)	5.312	0.000	0.000	0.000

(U) Schedule Profile:

Plan	Milestones
Metal Storm (MS)	
Sep 01	MS: Complete physics of scaling study.

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Oct 01	MS: Demonstrate preliminary design firing.
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)

Jun 01	RST-V: Demonstrate RST-V system capabilities in Advanced Warfighting Experiment (AWE).
Nov 01	RST-V: Demonstrate V-22 compatibility.
Dec 01	RST-V: RST-V/ C^4I testing complete.
Apr 02	RST-V: Deliver vehicles 1, 2, 3, and 4.
May 02	RST-V: Final Report.

Tactical Mobile Robotics (TMR)

Jul 01	TMR: Complete operational demonstrations of Tactical Mobile Robotic systems. Initiate transition and technology transfer plans.
Dec 02	TMR: Complete transition and technology to military services.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Small Unit Operations LNW-02	42.595	36.032	43.075	38.600	59.000	66.600	82.300	83.600	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 fusion 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 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 and Advanced Sensing Technologies and Urban 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 US 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 permit vulnerability and access to the target signatures. This program completes 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 military can use general-purpose robots to perform tasks that may be onerous or dangerous to human personnel or that exceed the capacity of the current force structure. The Robotics program 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. In addition, power generation and actuation at efficiencies and scale compatibility with these systems will be developed and demonstrated. Geo-spatial information systems (GIS) data is currently in expanding use commercially for a variety of applications from agriculture to environmental to traffic studies. The Combat Geographic Information Systems for Robotics (CGIS-R) will leverage the existing GIS software infrastructure and develop automatic and efficient GIS plug-ins to generate appropriate resource allocation and planning maps for use by military commanders and robotic vehicle controllers. This data is also likely to be downloadable to robotic platforms to assist them in generating robust "understanding" of the environment along the routes of their deployment.

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

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

- Situational Awareness System. ($ 31.157 Million) [Future Combat Systems – related = $17.900 Million]
  - Completed development of the Individual Warfighter Situational Awareness System (IWSAS), Warfighter Tactical Associate (WTA)-Base, WTA Mobile and Relay/Router/Beacon detailed hardware design, software modules and network protocols.

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- Completed Individual Warfighter/WTA software coding.
- Completed IWSAS, WTA-Base, WTA-Mobile, Relays and network code development and testing.
- Completed situation awareness (planning, tasking, sensor control, navigation and alerts) application software coding and testing.
- Completed brassboard fabrication of the major SAS elements (IWSAS, WTA and Relays).
- Conducted performance assessment of Phase 3 brassboard design.
- Verified that Individual Warfighting Situational Awareness System (IWSAS), Warfighter Tactical Associate (WTA) and Relay Radio Frequency (RF) propagation in multipath, jamming and open environments meets Service objective.
- Verified geolocation accuracy and navigation performance in urban and field environments.
- Developed Wolfpack system architecture and conduct system level trades to develop subsystem requirements.
- Determined the optimum use of legacy systems for IPB and cueing, and potential modifications required for coordinated spectrum access.

• Tactical Sensors. ($ 8.604 Million)
- Continued development of internetted remote control sensors to detect, localize and characterize targets.
- Continued development of surveillance and targeting sensors systems for dispersed operations.
- Developed mature application performance requirements for optical tags.
- Developed optical tag performance prediction modeling capability.

• Advanced Sensing Technologies. ($ 2.834 Million)
- Completed and tested breadboard sensor.
- Initiated brassboard development.

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

• Situational Awareness System. ($ 13.691 Million)
- Complete fabrication of Individual Warfighting System Situational Awareness System (IWSAS), Warfighter Tactical Associate (WTA) Mobile and Base, tactical sensors and tactical relays for test.
- Integrate IWSAS, WTA-Mobile and Base with external legacy communications, data and sensor equipment.

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- Test integrated system and conduct performance assessment of final Phase 3 design; measure IWSAS, WTA and Relay Radio Frequency (RF) propagation in multipath, jamming and open environments.
- Complete development of detailed demonstration scenarios to test and evaluate performance under operational conditions.

• Tactical Sensors. ($ 8.151 Million)
- Continue development of internetted remote control sensors and fusion algorithms to detect, localize and characterize targets.
- Continue development of surveillance and targeting sensors sytems for dispersed operations.

• Optical Tags. ($ 5.072 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. ($ 3.020 Million)
- Complete brassboard and initiate fieldable sensor development.

• Wolfpack. ($ 6.098 Million)
- Initiate system design and performance analysis.
- Conduct analysis for the applicability of distributed ground jammers to attack surface to air radar systems.
- Initiate development of networked, distributed jamming enabling technologies.

(U) **FY 2002 Plans:**

• Situational Awareness System. ($ 10.586 Million)
- Complete prototypes.
- Perform setup of field demonstration.
- Develop training materials and conduct soldier training for field demonstration.

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- Conduct field demonstration to verify communications performance in urban, forested and mountaneous terrain when operated by warfighters. Show the use of multiple organic sensors being operated by battalion and below warfighters.

• Optical Tags. ($ 10.586 Million)
  - Verify basic tag prototype design in lab setting tests.
  - Conduct engineering tests of improved tags for more stressing situations.

• Tactical Sensors. ($ 4.182 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 node.

• Wolfpack. ($ 12.721 Million)
  - Continue development of enabling technologies.
  - Complete system design and performance analysis.

• Robotics ($ 5.000 Million)
  - Select and refine several robotic arm-and-grasp designs and test on a broad array of common manipulation tasks. Integrate each of these with a robotic vehicle and study the effect of manipulation on balance and power requirements. Demonstrate the physical feasibility and utility of manipulation for ground robots in the 4, 40, and 400 pound range.
  - Initiate development of an integrated suite of sensors required for appropriate manipulator behavior.
  - 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.
  - Develop concepts for advanced power and actuation schemes for biomimetically inspired robots.
  - Conduct high fidelity GIS data collection at military operational areas.
  - Develop integrated software for operation on GIS data in the context of military robot behaviors.

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(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Situational Awareness System:	
Jun 01	Complete SAS software coding.
Dec 01	SAS engineer development model fabricated.
Jun 02	SAS prototypes fabricated.
Sep 02	SAS final demonstration.
Tactical Sensors:	
Sep 01	Complete micro-UGS field demonstration tests.
Dec 01	Design review for deployment and C^2 architecture.
Jul 02	Participate in field exercise.
Optical Tags:	
Jun 01	Develop improved response tag requirements and predict performance.
Jul 01	Basic tag performance predicted.
Jan 02	Design and test basic tag prototype.
Jul 02	Test improved response tag prototype.
Sep 03	Basic tag system field test.
Advanced Sensing Technologies:	
Sep 01	Demonstrate final brassboard.

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Wolfpack:

Oct 01	Initial Technology Run and System Definition.
Apr 02	System Design/Technology Assessment Review.
Oct 02	Initial enabling technology demonstrations.
Aug 03	Initial jammer subsystems demonstrated in laboratory.
Sep 03	Final Enabling Technology Demonstrations.
Jul 04	Subsystem field-testing completion.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Future Combat Systems LNW-03	0.000	61.000	90.000	122.000	62.900	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 to evaluate competitive concepts. The FCS program 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; adverse-weather reconnaissance, surveillance, targeting and acquisition (RSTA).

(U) The Government run experiments will consist of a series of hardware, and simulation based, experiments. The objective of these experiments will be to test key assumptions about how key technologies and components within the FCS Unit Cell and/or Unit of Action will need to perform. These experiments will focus on hardware experiments with surrogates and modeling and simulation in the early stages and then evolve to actual hardware in the loop experiments as key components and systems become available. The goal will be to conduct a series of simple, rapid turnaround experiments, that maintain traceability to concrete FCS Unit Cell and /or Unit of Action mission desires.

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(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 air vehicles and organic all weather targeting.

(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.

(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 accommodating 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. Future operations involving FCS technologies and operational capabilities cannot be restricted by a less responsive C^2 architecture. 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. 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 will be developed and validation of the architecture and assessment of performance (e.g., command latencies) will be achieved by conducting a series of experiments with combined simulated and real operational units.

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(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 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 (<100 lbs) air vehicle that can fly autonomously in adverse weather. It will leverage DARPA Micro Air Vehicle program technologies and design a vehicle that is scalable to accommodate varying missions and payloads. For example, the OAV program will fly the Jigsaw LADAR (Laser Radar) sensor in 2003 to demonstrate its utility for the FCS concept.

(U) The Jigsaw program will develop advanced LADAR sensor systems and technologies for all weather 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) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- This program was funded in FY 2000 from Project LNW-01, Rapid Strike Force Technology, within this same Program Element.

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(U) FY 2001 Plans:

- FCS Concept Development. ($ 15.000 Million)
  - Continue Concept Development Activities including the identification of key technologies, technology tradeoffs, and technology roadmaps.
  - Establish program Integrated Data Environment (IDE).
  - Develop detailed Program Acquisition Strategy.
  - Initiate Government Experiment activities to identify critical questions and understand the impacts of selected solutions.
  - Define program metrics and structure modeling and simulation activities to address those metrics.
  - Develop baseline operational documentation.
  - Identify the role of FCS as it relates to the Army's vision of an Objective Force.

- FCS Supporting Technologies. ($ 46.000 Million)
  - PerceptOR.
    - - Develop unmanned maneuver algorithms that use a combination of on-board and off-board sensors and terrain data to maximize the level of autonomous operation.
    - - Develop surrogate perception prototypes for testing in FY02.

  - Unmanned Ground Combat Vehicle (UGCV).
    - - Complete Phase I study of UGCV design drivers. Highlight critical technologies for achieving higher mobility and endurance in configurations associated with both combat and support duty vehicles in the context of the FCS mission.
    - - Initiate Phase II work on UGCV long lead critical technology testbeds with traceability to fieldable UGCV concepts.

  - Maneuver C^3.
    - - Develop top-level system architecture for fully integrated C^2 system.
    - - Initiate the design of the C^2 architecture for the lowest, integrated FCS echelon (“unit cell”).
    - - Examine potential wireless communications network architectures.
    - - Develop technologies for assured communications in a hostile environment using novel waveforms and beam steering antennas for low probability of detection and anti-jam.

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– Netfires.
  - - Continue system hardware and software development for missiles, container/launchers and command/control units.
  - - Complete critical component demonstrations for motor, seeker, navigation and data link.
  - - Plan and initiate preparations for flight test demonstrations.

– Organic All-Weather Targeting Vehicles.
  - - Determine requirements for organic air vehicles to be used as sensor platforms.
  - - Develop air vehicles capable of operating in adverse weather.
    - Define A160 systems for operating in adverse environments: rain, icing, sand/dust, salt spray, and turbulence.
    - Define A160 SAR/MTI radar sensors and design Radar/A160 interfaces.
    - Carry out A160 (30 kft) flight test.
    - Design and initiate fabrication of Organic Air Vehicle (OAV) capable of autonomous flight.
    - Conduct OAV integrated technology systems demonstration.

– Jigsaw: LADAR Sensing for Combat ID.
  - - Initiate development of technology that can identify hidden targets by combining multiple LADAR images penetrating holes in the foliage and obscuring material and integrating information from multiple infrared-based LADAR images.
  - - Conduct trade studies to determine best technological approach to LADAR sensing for FCS application, including lasing, detection, and data processing.
  - - Conduct preliminary design reviews for prototype LADAR sensors for airborne captive carry operation.

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

- FCS Concept Development. ($ 30.000 Million)
  – Evaluate team concepts via modeling, simulation and specialized analysis.
  – Prepare Phase II program plans.
  – Perform concept downselect to two options.
  – Transition from concept development effort to preliminary design.

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– Continue Government Experiments exploring and defining critical FCS Unit Cell and/or Unit of Action performance parameters using surrogates and modeling an simulation. These experiments will investigate issues including, but not limited to: work load associated with tasking and controlling multiple type and quantities of Unmanned Air Vehicles (UAVs), Unmanned Ground Vehicles (UGVs) and sensors, fusion of data from multiple sensor types, and communication.

- FCS Supporting Technologies. ($ 60.000 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).
- - Continue work on Phase II technology testbeds and complete initial testing.
- - Update operational concepts based on testbed fabrication and testing results.
- - Plan and initiate preparations for integrated UGCV testbeds use in operational exercises.
- - Conduct field-testing with upgraded surrogate.

– Maneuver C^3.
- - Develop simulations for the integrated “unit cell” C^2 architecture.
- - 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.

– Netfires.
- - Initiate ballistic test vehicle and controlled test vehicle demonstrations.
- - Complete pintle motor development and testing.

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– Organic All-Weather Targeting Vehicles.
  - - Select platform and sensory payload for detailed design and prototyping efforts.
  - - Initiate detailed design efforts.
  - - Ground test A160 anti-icing systems, sand/dust/salt protection systems, and precision flight systems.
  - - Integrate SAR/GMTI Radar on A160 vehicle.
  - - Complete fabrication of AV 003.
  - - 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 critical design reviews for alternative prototype LADAR sensors.
  - - Build prototype LADAR sensors, collect data, and conduct experiments.

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

	FY 2000	FY 2001	FY 2002
PE 0602601A Combat Vehicle and Automotive Technology	0.000	7.752	19.564
PE 0603005A Combat Vehicle and Automotive Advanced Technology	0.000	5.312	61.586

(U) **Schedule Profile:**

Plan	Milestones
Aug 01	End of concept development by contractors.
Sep 01	Complete Unmanned Ground Combat Vehicle (UGCV) early surrogate tests of high-risk/long-lead technologies.
Sep 01	Flight Test of A160.
Nov 01	Initiate FCS design Competition.
Dec 01	Demonstrate Organic Air Vehicle (OAV) gust stability and inner loop control.
Jan 02	PerceptOR: Conduct initial unrehearsed field-testing of robot perception system prototypes.

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Feb 02	Complete UGCV technology testbed data collection.
Mar 02	FCS Downselect (end of Phase I efforts).
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).
Apr 02	Complete FCS design competition.
May 02	Complete UGCV integrated testbed detailed design and procure long lead items for fabrication.
May 02	Award FCS Concept Design and Demonstration Agreements.
Jun 02	Complete A160 AV003.
Jun 02	Preliminary data collections using prototype Jigsaw LADAR sensors.
Sep 02	Rollout UGCV first integrated testbed baseline configuration.
Oct 02	SAR/GMTI Radar first flight on A160.
Nov 02	Validate OAV adverse weather flight capability.
Dec 02	Demonstration of capability to ID targets using LADAR data from prototype Jigsaw sensors, combining data from multiple views.
Jan 03	Anti-icing system first flight on A160.
Jan 03	PerceptOR: Conduct unrehearsed field-testing of improved perception system prototypes in extreme terrain and degraded conditions.
Jan 03	Demonstrate OAV waypoint flight with collision avoidance.
Feb 03	Initiate FCS Program Risk Reduction/Concept.
Mar 03	Army decision on FCS technology readiness levels.
May 03	Complete UGCV fabrication of all integrated testbed vehicles and prepare for field-testing.
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 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, R-1 #126

COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	32.163	32.379	36.937	38.414	40.600	40.900	41.000	41.200	Continuing	Continuing
Management Headquarters (R&D) MH-01	32.163	32.379	36.937	38.414	40.600	40.900	41.000	41.200	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 whose salary, benefits and bonuses (totaling approximately $150,000 per employee) is now 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 2000 Accomplishments:

- Management Headquarters. ($ 32.163 Million)
  - DARPA continued to fund civilian direct-hires and administrative support service costs. Salary reimbursement for IPAs was funded with program funds in keeping with OMB policy. Reductions associated with this change were substantially offset by the additional costs of the Section 1101 experimental hiring program.

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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

(U) FY 2001 Plans:

- Management Headquarters. ($ 32.379 Million)
  - DARPA will continue 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 are also funded.

(U) FY 2002 Plans:

- Management Headquarters. ($ 36.937 Million)
  - DARPA will continue to fund civilian direct-hires, employees and administrative support costs. Anticipated pay raise requirements are also funded. Salary, benefits and bonus requirements for an additional 20 Section 1101 employees ($3 million) authorized by the FY 2001 Defense Authorization Act are included. Finally, the costs associated with statutory financial statement preparation and audit, a requirement arising from the Chief Financial Officer Act, are also included.

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

	FY2000	FY 2001	FY2002
Previous President's Budget	32.103	34.679	35.954
Current Budget	32.163	32.379	36.937

(U) Change Summary Explanation:

FY 2000	Increase reflects mandated pay raise requirements.
FY 2001	Decrease reflects congressional program reduction, Section 8086 reduction and the government-wide rescission.
FY 2002	Increase reflects the addition of 20 Section 1101 experimental hires, pay raises and the costs associated with CFO Act compliance. The experimental hires replace Intergovernental Personnel Act employees funded outside the Management Headquarters PE.

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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

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

- Not Applicable.

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

- Not Applicable.

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