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Department of Defense Fiscal Year (FY) 2007 Budget Estimates

February 2006

RESEARCH, DEVELOPMENT, TEST AND EVALUATION, DEFENSE-WIDE

Volume 1 - Defense Advanced Research Projects Agency

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DEPARTMENT OF DEFENSE
FY 2007 Budget Estimates

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DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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Defense Adv Research Projects Agcy
FY 2007 RDT&E PROGRAM

EXHIBIT R-1

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

Date: FEB 2006

Line No	Program Element Number	Item	Act	FY 2005	FY 2006	FY 2007	SEC
				Thousands of Dollars			
2	0601101E	Defense Research Sciences	01	165,101	133,308	150,690	U
	Basic Research			**165,101**	**133,308**	**150,690**	
11	0602303E	Information & Communications Technology	02	182,815	195,991	242,852	U
12	0602304E	Cognitive Computing Systems	02	145,833	163,430	220,085	U
13	0602383E	Biological Warfare Defense	02	155,360	148,108	112,242	U
15	0602702E	Tactical Technology	02	316,673	346,076	383,680	U
16	0602715E	Materials and Biological Technology	02	252,168	288,753	297,277	U
18	0602716E	Electronics Technology	02	254,514	239,959	246,978	U
	Applied Research			**1,307,363**	**1,382,317**	**1,503,114**	
29	0603286E	Advanced Aerospace Systems	03	66,919	54,594	115,829	U
30	0603287E	Space Programs and Technology	03	217,004	216,357	254,913	U
41	0603739E	Advanced Electronics Technologies	03	216,824	220,877	248,627	U
44	0603760E	Command, Control and Communications Systems	03	213,971	213,316	232,489	U
45	0603764E	Land Warfare Technology	03	60,897	125,384	48,975	U
46	0603765E	Classified DARPA Programs	03	148,933	160,213	151,598	U
47	0603766E	Network-Centric Warfare Technology	03	118,538	134,944	174,276	U
48	0603767E	Sensor Technology	03	196,594	186,746	205,519	U
49	0603768E	Guidance Technology	03	111,145	101,797	157,367	U
	Advanced Technology Development (ATD)			**1,350,825**	**1,414,228**	**1,589,593**	
137	0605502E	Small Business Innovative Research	06	75,374			U

Defense Adv Research Projects Agcy
FY 2007 RDT&E PROGRAM

EXHIBIT R-1

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

Date: FEB 2006

Line No	Program Element Number	Item	Act	FY 2005	FY 2006	FY 2007	SEC
				Thousands of Dollars			
144	0605898E	Management HQ - R&D	06	48,582	48,765	50,951	U
		RDT&E Management Support		**123,956**	**48,765**	**50,951**	
		Total Defense Adv Research Projects Agcy		**2,947,245**	**2,978,618**	**3,294,348**	

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PROGRAM ASSESSMENT

PROGRAM
View Similar Programs

Defense Basic Research

This program supports scientific study and experimentation to increase fundamental knowledge in the physical, engineering, environmental and life sciences of potential importance to the defense mission. The program is carried out primarily through grants to universities and non-profit organizations.

RATING
What This Rating Means

PERFORMING

Effective

- **The program has clear purposes.** It helps develop technologies that provide options for new weapons, helps prevent technological suprise by adversaries and develops new scientists who will contribute to the DoD mission in the future.
- **The program is reviewed regularly by technically capable outside expets, who recommend improvements they believe should be implemented.** The experts indicate that the work is of overall high quality.
- **Research earmarks have increased dramatically in the past 15-20 years.** Such projects contribute less than typical projects to meeting the Department's mission, as they don't have to be screened for relevance or quality, and cost more to administer. Earmarks also reduce incentives for other projects to perform to peak potential, as non-earmarked projects encounter less competition for funding.

IMPROVEMENT PLAN
About Improvement Plans

We are taking the following actions to improve the performance of the program:

- Emphasizing the use of independent review panels in assessing the performance of the program.
- Working with the research community and Congress to explain the need to limit claims on research grant funds to proposals that independently can meet the standards of a strict merit-review process.

LEARN MORE

- **Details and Current Status of this program assessment.**
- How all Federal programs are assessed.
- Learn more about Defense Basic Research.

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PROGRAM ASSESSMENT

PROGRAM

View Similar Programs

Defense Applied Research Program

This program supports scientific study of physical, biomedical, behavioral or other phenomena to determine the means by which a particular military need may be met. This work is a little more advanced and applied than the basic research from which it may arise.

RATING

What This Rating Means

PERFORMING

Moderately Effective

- **Program purpose and design are clear.** The purpose is to support quality science with potential application to the defense mission. The Department has established methodical processes for setting program goals and for reviewing progress.
- **Reviews of the program by external review panels are not independent of program officials.** Some reviewers are government employees with financial associations to the program areas under review.
- **A large part of the program is executed either without the benefit of military or scientific expertise in choosing the funded work or without allowing the applications process to be open to all capable researchers.** Earmarking of projects in the program has increased in the recent past and has led to these problems.

IMPROVEMENT PLAN

About Improvement Plans

We are taking the following actions to improve the performance of the program:

- Ensuring that adequate funding exists to carry promising basic research results through the applied research phase.
- Changing the expert evaluation process to use fully independent review panels in assessing the performance of the program.
- Working with the research community and Congress to explain the need to limit claims on research grant funds to proposals that independently can meet the standards of a strict merit-review process.

LEARN MORE

- **Details and Current Status of this program assessment.**
- How all Federal programs are assessed.
- Learn more about Defense Applied Research Program.

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PROGRAM ASSESSMENT

PROGRAM
View Similar Programs

Defense Small Business Innovation Research / Technology Transfer

This program uses funding set aside specifically for small businesses to investigate the potential for new technologies to help meet the Department's mission and funds the early stage of development of such technologies by small businesses.

RATING
What This Rating Means

NOT PERFORMING

Results Not Demonstrated

- **Provides funds to small businesses, but has poor controls on unproductive spending.**
- **Continues to provide funding to companies with track records of poor performance.**
- **Overestimates commercial successes resulting from Federal support by counting additional investment on par with product sales as measures of success.** Product sales are the ultimate measure of success in the marketplace.

IMPROVEMENT PLAN
About Improvement Plans

We are taking the following actions to improve the performance of the program:

- Tightening eligibility requirements for accepting proposals from companies and individuals that repeatedly fail to sell resulting products in the marketplace.
- Changing the way companies' past performance is assessed to ensure that it more closely matches the intent of the law (Section 638 of Title 15, USC) that the program support product commercialization.
- Seeking to get highly successful awardees to enter the mainstream of Defense contracting.

LEARN MORE

- **Details and Current Status of this program assessment.**
- How all Federal programs are assessed.
- Learn more about Defense Small Business Innovation Research/Technology Transfer.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2006

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

COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	165.101	133.308	150.690	153.460	156.242	159.959	162.596
Bio/Info/Micro Sciences BLS-01	53.879	44.042	46.266	49.645	53.925	54.925	55.925
Information Sciences CCS-02	23.791	19.933	29.481	32.687	30.627	31.314	32.951
Electronic Sciences ES-01	33.815	30.783	34.060	30.853	30.752	31.752	31.752
Materials Sciences MS-01	53.616	38.550	40.883	40.275	40.938	41.968	41.968

(U) Mission Description:

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

(U) The Bio/Info/Micro Sciences project will explore and develop potential technological breakthroughs that exist at the intersection of biology, information technology and micro/physical systems to exploit advances and leverage fundamental discoveries for the development of new technologies, techniques and systems of interest to the DoD. Programs in this project will draw upon information and physical sciences to discover properties of biological systems that cross multiple biological architectures and functions, from the molecular and genetic level through cellular, tissue, organ, and whole organisms' levels. Key focus areas include multidisciplinary programs in BioComputational Systems; Simulation of Bio-Molecular Microsystems; Bio Interfaces; Biological Adaptation, Assembly, and Manufacturing; Nanostructure in Biology; and Human Assisted Neural Devices.

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

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2006
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(U) The Electronic Sciences project explores and demonstrates electronic and optoelectronic devices, circuits and processing concepts that will provide: (1) new technical options for meeting the information gathering, transmission and processing required to maintain near-real time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near-real time; and (2) provide new means for achieving substantial increases in performance and cost reduction of military systems providing these capabilities.

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

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

	FY 2005	FY 2006	FY 2007
Previous President's Budget	169.571	130.090	132.041
Current Budget	165.101	133.308	150.690
Total Adjustments	-4.470	3.218	18.649
Congressional program reductions	-0.130	-5.432	
Congressional increases	0.000	8.650	
Reprogrammings	0.000		
SBIR/STTR transfer	-4.340		

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2006
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(U) **Change Summary Explanation:**

FY 2005	Decrease reflects SBIR/STTR transfer and the DOE transfer directed in P.L. 108-447.
FY 2006	Increase reflects five congressional adds in the areas of biomedical engineering, quantum computing and infotonics offset by a congressional reduction to the Bio-computational program and undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Increase reflects new emphasis in Project CCS-02 for the Computer Science Study Group; Project ES-01 to fund Carbon Nanotube RF Devices, Quantum Entanglement S&T (QUEST) and MEMS Science and Technology Focus Centers; and enhancement of Bio-Molecular thrusts in the Materials Sciences area, Project MS-01.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2006
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Bio/Info/Micro Sciences BLS-01	53.879	44.042	46.266	49.645	53.925	54.925	55.925

(U) Mission Description:

(U) This project is investigating and developing the intersections of biology, information technology and micro/physical systems to exploit important technological advances and leverage fundamental discoveries for the development of new technologies, techniques, and systems of interest to the DoD. This research is critical to the development of rapid responses to engineered biological warfare agents, radically new biomolecular computers, and novel materials for the DoD. Programs in this project will draw upon the information and physical sciences to discover properties of biological systems that cross multiple scales of biological architecture and function, from the molecular and genetic level through cellular, tissue, organ, and whole organism levels. This project will develop the basic research tools in biology that are unique to the application of biological-based solutions to critical Defense problems. This project is also providing the supporting basic research for the effort to revolutionize prosthetics.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
BioComputational Systems	9.237	3.000	0.000

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

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

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

(U) Technical challenges to developing Bio-SPICE are being met through the development of four-dimensional (4-D) computational models and simulation techniques, and by leveraging cognitive information processing tools. To transition the technology, the program is collaborating with several DoD client agencies including Defense Threat Reduction Agency (DTRA), U.S. Army Medical Research and Material Command (USAMRMC), Soldier Biological and Chemical Command (SBCCOM), Walter-Reed Army Institute for Research (WRAIR), Naval Medical Research Command (NMRC), the U. S. Air Force Toxicology program, and the Center for Disease Control and Prevention (CDC).

(U) Program Plans:

- Developed a progressively sophisticated suite of dynamic cellular models and architecture for Bio-SPICE which will enable modeling, prediction, and control of cellular processes. Continually validate results through experimentation.
- Incorporated spatial models into Bio-SPICE and explore potential reduced-order models to analyze the non-linear and stochastic dynamics of several hundred interactions.
- Built baseline models of intra-cell processes of interest to DoD, such as spore formation in bacteria like anthrax, bacterial cell division and growth, and cell death induced by toxins from bio-warfare agents (apoptosis). Identify candidate molecular targets for intervention strategies in sporulation (such as for therapeutics and safe decontamination), cell cycle control, and other processes in defense against bio-agents.
- Demonstrated computer analysis methods for commanders to use in the threat assessment of natural and emerging bio-agents. These methods, which predict pathogenicity and virulence of agents from their genomic information, were demonstrated for several bacterial pathogen cases (staphylococcal enterotoxin B [SEB], E coli), and resulted in far more information than today's costly wet-experiments.
- Identified new methods for early detection of exposure of soldiers to pathogens and toxins using molecular (gene expression) signatures, which is vital for early intervention and avoidance of death. These methods demonstrated a 95% accuracy rate in identifying exposure to host cells among a set of ten pathogens.

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– Develop a framework for describing and representing biological knowledge that spans data from the molecular (genomic, proteomic) to clinical level, and across organisms, to support deep and rapid knowledge extraction.
– Implement cutting edge learning and reasoning algorithms that act on vast amounts of biological, experimental and simulation data; and demonstrate rapid reasoning and knowledge-acquisition.

	FY 2005	FY 2006	FY 2007
Simulation of Bio-Molecular Microsystems (SIMBIOSYS)	5.160	5.000	0.000

(U) The Simulation of Bio-Molecular Microsystems (SIMBIOSYS) program is developing methods and tools to simulate and design Bio-Molecular Microsystems to dramatically improve the interaction and integration of biological elements with synthetic materials. This is being accomplished by exploring fundamental properties and compatibility of biological elements at the molecular surface level through experimental and theoretical analyses. Key phenomena under study 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.

(U) Program Plans:
– Demonstrate high (signal to noise ratio [SNR] > 10) transduction of molecular signals into measurable electrical and mechanical signals using nanopores, micro/nano-cantilevers, and nanoparticles; demonstrate SNR ~ 100 using solid-state nanopores for DNA translocation and using nanopores for ultraselective DNA detection; demonstrate models to correlate transduced signal intensity to bio-molecular structure and binding events.
– Demonstrate that, using microcantilevers, a nanoparticle conjugation can successfully enable detection of 10-100 atto-molar DNA concentrations with single base pair selectivity without performing polymerase chain reaction; transition to other DoD agencies and Homeland Defense.
– Demonstrate low power transport (~ 10X reduction in power) of fluids by modulating surface tension in droplet based transport.

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

- Demonstrate surface-tension modulated transport of droplets on a substrate; demonstrate computational models to optimize transport characteristics.
- Demonstrate orders of magnitude (> 100X) improvement in microfluidic mixing using electrokinetic and Magneto Hydrodynamic (MHD) schemes (based on modeling studies).
- Develop scaling laws and phenomenological models for bio-molecular phenomena such as molecular recognition, signal transduction and bio-fluidic transport processes in bio-microfluidic systems; develop and implement scaling laws into microfluidic system modeling software to enable design of lab-on-a-chip systems.
- Design novel hybrid macro-molecular devices that form specific and controlled transducing functions at the molecular scale; demonstrate design of maltose binding proteins and ion channels with desired selectivity and sensitivity using computational tools.
- Design and demonstrate working devices that incorporate biological elements as sensors, actuators and computational devices.

	FY 2005	FY 2006	FY 2007
Bio Interfaces	4.000	3.500	8.500

(U) The Bio Interfaces program will support scientific study and experimentation, emphasizing the interfaces between biology and the physical and mathematical/computer sciences. This unique interaction will develop new mathematical and experimental tools for understanding biology in a way that will allow its application to a myriad of DoD problems. Chief among them is the ability to seamlessly integrate and control mechanical devices and sensors within a biological environment – a critical aspect in the successful implementation of a major prosthetics effort. In addition, these tools will help exploit the advances in the complex modeling of physical phenomena such as Electro-Magnetic Pulse (EMP) and blast with biological tissues and cells in order to understand and prevent the deleterious effects of traumatic brain injury. It is also expected that understanding the fundamentals of biology will aid in developing tools to understand complex, non-linear networks and force structures.

(U) Program Plans:

- Examine behavior of materials/biological interfaces to improve performance and biocompatibility of mechanical and microelectronic devices for ultimate integration into new prosthetic devices.
- Develop mathematical approaches and new microelectronic devices for sensing and controlling biological responses.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2006
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

- Develop predictive biologic models that take into account the materials and chemical properties of the brain to account for all blast effects including characteristics of the pressure wave, electromagnetic pulse, acoustics, etc.
- Demonstrate and validate novel mathematical tools for analyzing and interpreting complex data sets obtained from complex biological systems and behavior. Extend these tools to other problems of interest to DoD.
- Develop new mathematics that predicts fundamental biological processes across biological size and times scales.

	FY 2005	FY 2006	FY 2007
Biological Adaptation, Assembly and Manufacturing	11.200	9.000	12.500

(U) The Biological Adaptation, Assembly and Manufacturing program will examine the structure, function, and informational basis underlying biological system adaptation, particularly to harsh environments, and the factors employed by the organism to assemble and manufacture complex biological subsystems. The unique stability afforded biological systems in their ability to adapt to wide extremes of physical and endurance (e.g., heat, cold, and sleeplessness) parameters will be examined and exploited in order to engineer stability into biological systems of Defense needs (such as blood or other therapeutics). In addition, the fault tolerance present in biological systems will be exploited in order to assemble and manufacture complex physical and multi-functional systems, both biological and abiotic. Further activity in this area will investigate the adaptability of the brain to information processing and situational awareness. Applications to Defense systems include the development of chemical and biological sensors, and improved battlefield survivability of the warfighter.

(U) Program Plans:

- Identify promising strategies in nature that allow organisms to survive under environmental extremes and adapt those strategies to other cells, tissues, organs and organisms, including platelets and red blood cells.
- Understand how cells and organisms can be adapted to respond to environmental chemicals and toxins of interest to DoD by producing signals (colors, fluorescence) that can be detected remotely.
- Understand how cells differentiate/heal into functional tissues using naturally occurring mechanisms and adapt these naturally occurring mechanisms to develop the ability to regenerate appropriate tissue and structure at a wound site rather than scarring.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2006
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

- Demonstrate the adaptation of bacteria to the digestion of cellulose in disaccharides to enable the ability to use fiber as nutrition and for the prevention of dysentery.
- Understand how the brain adapts to cognitive overload and develop novel methods for delivering information that can be more effectively processed by the brain.

	FY 2005	FY 2006	FY 2007
Nanostructure in Biology	10.382	10.042	13.266

(U) The Nanostructure in Biology program will investigate the nanostructure properties of biological materials to better understand their behavior and accelerate their exploitation for Defense applications. This new information about biomolecules will provide important new leads for the development of threat countermeasures, biomolecular sensors and motors, and molecular interventions to maintain human performance in the battlefield. This program will also develop approaches to mathematically predict a priori the structure of biological materials, especially proteins, based on the desired performance. This will enable the rapid design of new biosensors against previously unknown threats and the design of advanced catalysts based on biological activity to produce new materials of interest to DoD (e.g., tailored explosives). The program will also create technology to reliably integrate nanoscale and microsystems payloads on insects that will extract power, control locomotion, and also carry DoD relevant sensors. In addition, research will be conducted in the interaction, at the nanoscale, of biotic and abiotic materials and functions, a critical aspect in the development of advanced prosthetics.

(U) Program Plans:

- Investigate fundamental issues of nanowire communication with electrically active biological systems (neurons) including high density recording, information processing, stimulation patterns, and new computational methods of analysis.
- Demonstrate image formation through the use of microchip-driven wire to simultaneously stimulate thousands of retinal neurons.
- Use nanostructured neural interfaces to develop an understanding of the neural information and algorithms used for biological visual processing (e.g., object recognition).
- Demonstrate the ability to rapidly (hours as opposed to weeks or months) predict new protein structures that inactivate new biological pathogens or toxins.

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

- Demonstrate approaches for making enzymes that catalyze chemical reactions not performed by natural enzymes for the synthesis of chemicals of interest to the Department of Defense.
- Demonstrate locomotion control of insects using MEMS platforms consisting of ultrasonic projectors, pheromone ejectors, insect mechano-sensor activation, and visual presentation manipulation, neural, or muscular interfaces.
- Demonstrate power scavenging from insects via thermal-to-electric, and/or mechanical-to-electrical power conversion using embedded micro power generators.

	FY 2005	FY 2006	FY 2007
Human Assisted Neural Devices	12.000	12.000	12.000

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

(U) Program Plans:

- Extract neural and force dynamic codes related to patterns of motor or sensory activity required for executing simple to complex motor or sensory activity (e.g., reaching, grasping, manipulating, running, walking, kicking, digging, hearing, seeing, tactile).
- Determine necessary force and sensory feedback (positional, postural, visual, acoustic, and other) from a peripheral device or interface that will provide critical inputs required for closed-loop control of a prosthetic.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2006
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

- Explore new methods, processes, and instrumentation (e.g., Magnetoencephalography, optical, IR, and RF) for accessing neural codes non-invasively at appropriate spatiotemporal resolution to provide closed-loop control of a peripheral device.
- Identify robust neural signals that respond to visually salient objects and demonstrate that those neural signals can be used to significantly (3x) improve throughput in visual analysis tasks such as imagery analysis compared to using an individual's visuomotor transformation (i.e., movement) based response.
- Investigate the underlying mechanisms of perception and cognition and use these to develop optimal approaches to radically improve neural plasticity in soldiers under stressful operational conditions.

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

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

	FY 2005	FY 2006	FY 2007
Biomedical Engineering Initiative	0.000	1.500	0.000

(U) Development of technologies to enable Biomedical Engineering.

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

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)							DATE February 2006
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 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Information Sciences CCS-02	23.791	19.933	29.481	32.687	30.627	31.314	32.951

(U) Mission Description:

(U) This project supports scientific study and experimentation on new computational models and mechanisms for reasoning and communication in complex, interconnected systems in support of long-term national security requirements. The project is exploring novel means of exploiting computer capabilities; practical, logical and heuristic reasoning by machines; development of enhanced human-computer and computer-to-computer interaction technologies; innovative approaches to the composition of software; and new learning mechanisms for systematically upgrading and improving these capabilities. Promising techniques will transition to both ongoing and system-level projects.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Computer Expoitation and Human Collaboration	23.791	19.933	22.908

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

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understanding the warfighter and commander's combined natural communication and activity patterns; and fundamental technologies for integrating information expressed in different modalities and formats, which is currently a bottleneck to timely military situational awareness.

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

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

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(U) Program Plans:

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

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	FY 2005	FY 2006	FY 2007
Computer Science Study Group	0.000	0.000	6.573

(U) The Computer Science Study Group (CSSG) program funds emerging ideas from the computer science academic community to address DoD's need for information exploitation technology; to educate young principal investigators; to acclimate a generation of researchers to the needs and priorities of the Department of Defense; and to enable the transition of those ideas and applications by promoting joint university, industry, and government projects. The CSSG project formalizes and focuses this research for efficiency and greater effectiveness.

(U) Program Plans:

- Establish a Computer Science Study Panel (CSSP) hosted by the Institute for Defense Analysis (IDA), consisting of mentors from senior academic and military communities.
- Arrange seminars for CSSP participants, at sites around the country where participants can experience DoD information exploitation capabilities and shortcomings.
- Evaluate and approve proposals for major university research projects to conduct basic information technology research, based on knowledge gained in CSSP meetings.
- Solicit co-funding from industry or interested government parties to continue successful university research projects.
- Develop transition strategy with university participants and co-funding sources.

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

- Not Applicable.

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

COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Electronic Sciences ES-01	33.815	30.783	34.060	30.853	30.752	31.752	31.752

(U) Mission Description:

(U) This project seeks to continue the phenomenal progress in microelectronics innovation that has characterized the last decades by exploring and demonstrating electronic and optoelectronic devices, circuits and processing concepts that will: 1) provide new technical options for meeting the information gathering, transmission and processing required to maintain near real-time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near real-time; and 2) provide new means for achieving substantial increases in performance and cost reduction of military systems providing these capabilities. Research areas include new electronic and optoelectronic device and circuit concepts, operation of devices at higher frequency and lower power, extension of diode laser operation to new wavelength ranges relevant to military missions, development of uncooled and novel infrared detector materials for night vision and other sensor applications, development of innovative optical and electronic technologies for interconnecting modules in high performance systems, research to realize field portable electronics with reduced power requirements, and system and component level improvements to provide greater affordability and reliability. Additionally, electronically controlled microinstruments offer the possibility of nanometer-scale probing, sensing and manipulation for ultra-high density information storage "on-a-chip," for nanometer-scale patterning, and for molecular level analysis and synthesis. These microinstruments may also offer new approaches to integration, testing, controlling, manipulating and manufacturing nanometer-scale structures, molecules and devices.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
University Photonic Opto-Centers	7.072	8.000	8.000

(U) This program is dedicated to coupling university based engineering research centers of excellence with appropriate industry groups to conduct research leading to development of advanced optoelectronic components. Such components are critical to enhancing the effectiveness of military platforms that provide warfighter comprehensive awareness and precision engagement. Topics researched include emitters, detectors,

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

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

	FY 2005	FY 2006	FY 2007
Semiconductor Technology Focus Centers	10.000	10.000	10.000

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

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(U) Program Plans:

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

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

(U) Large dendritic and other highly branched organic molecules offer great potential for active photonic applications. Three-dimensional molecular structure and shape can be engineered to orient and immobilize optically active substituents to achieve much higher electro-optic activity than with traditional polymer systems. The ability to engineer molecular structure, shape, energy transport, and chemical composition offers the potential for distinct electronic energy level engineering without the traditional semiconductor crystal lattice. This will allow more freedom to tailor electromagnetic responses of individual molecules to achieve functionality not possible in semiconductors. Potential applications include: direct conversion of sunlight to power ("optical antenna"), inversion-less lasers and electromagnetically induced transparency (coherent organic emitters, and slow light materials), high performance photorefractive materials for signal processing and holographic memory, optical limiters and saturable absorbers as well as high performance modulators.

(U) Program Plans:

- Model and simulate advanced structures for four classes of applications.
- Improve modeling capability for predicting macro functionality from nanostructure.
- Emphasize chemical synthesis.

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- Address parameters such as thermal stability, environmental chemistry tolerance (O_2, H_20, etc) and photochemistry.
- Fabricate initial devices; continue modeling maturation.
- Final material synthesis, prototype device fabrications, characterization and demonstration.

	FY 2005	FY 2006	FY 2007
Photonics Technology Access Program (PTAP)	2.500	2.898	1.300

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

	FY 2005	FY 2006	FY 2007
Carbon Nanotube RF Devices	0.000	0.000	3.000

(U) The goal of the Carbon Nanotube (CNT) Devices Program is to explore the feasibility of amplifying a specific type of single-walled CNT with increased efficiency. In addition, this program will create the ability to integrate CNT with conventional electrical device architectures and fabrication processes in a cost-efficient and technologically-relevant way, i.e., scaleable (automated), spatially addressable, and high yield.

(U) Program Plans:
- Develop techniques for the low-cost, mass production of a single-configuration CNTs (i.e., uniform armchair, zigzag or helical type).
- Develop integrated circuit devices such as field-effect transistors (FETs), high-Q, low loss RF filters, amplifiers and antenna for selected applications.
- Reduce the losses in electronic circuitry, which increases efficiency and lowers power consumption.

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	FY 2005	FY 2006	FY 2007
Quantum Entanglement Science and Technology (QuEST)	0.000	0.000	4.698

(U) The Quantum Entanglement Science and Technology (QuEST) program will explore the research necessary to create new technologies based on quantum information science. Technical challenges include loss of information due to quantum decoherence, limited communication distance due to signal attenuation, and protocols, and larger numbers of quantum bits (Qubits) and their entanglement. A key challenge is to integrate improved single and entangled photon and electron sources and detectors into quantum computation and communication networks. Error correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Expected impacts include highly secure communications, algorithms for optimization in logistics, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking.

(U) Program Plans:
- Develop methods to mitigate loss of information due to decoherence.
- Develop techniques for rapid communication between non-adjacent qubits.
- Develop novel quantum algorithms.

	FY 2005	FY 2006	FY 2007
MEMS Science and Focus Centers	0.000	0.000	4.452

(U) The MEMS Science and Focus Centers effort is seeking research by means of multi-performer (university/nonprofit/industry/other) focus centers dedicated to advancing a number of core technologies considered essential to the advancement of MEMS and Nano-Electro-Mechanical Systems (NEMS) technology for applications important to the Department of Defense (DoD). The fundamental technology areas of interest for the program are: Surface Physics, Noise Mechanisms, Reliability Physics, Scaling Physics, Microfluidics, Interconnections, Single-Molecule Methods, Modeling, Signal Processing Methods, and other areas.

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

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

	FY 2005	FY 2006	FY 2007
Nanophotonics Systems Fabrication	2.850	0.000	0.000

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

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

(U) Program Plans:
- Developed novel lithographic devices and new processes.

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	FY 2005	FY 2006	FY 2007
Infotonics Research	0.000	2.000	0.000

(U) Program Plans:
- Initiate research in Infotonics technology.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Materials Sciences MS-01	53.616	38.550	40.883	40.275	40.938	41.968	41.968

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Nanoscale/Biomolecular and MetaMaterials	14.826	11.000	15.450

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

(U) Program Plans:
- Develop algorithmic approaches for predicting properties and structure of nano-scale and meta-materials using first principles/quantum mechanical methods with higher accuracy and reduced computational complexity.
- Couple the algorithmic approaches to methods that extract parameters for simulation of materials at larger spatial scales while conducting experiments to verify/validate the predicted properties at all spatial scales.
- Explore and exploit the underlying dualities between discrete and continuous computational methods to dramatically improve DoD computational abilities.
- Apply ideas from non-Euclidean geometry to obtain fast optimization methods for certain problems in robotics, including pursuit-evasion, optimal path-planning, and reconfiguration.
- Explore fundamental behavior of nanostructured materials that display quantum and/or non-equilibrium behavior.

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- Develop theoretical advances to characterize the propagation of random effects through differential equation models of electromagnetic material systems to allow interpolation, extrapolation, and hybridization of solutions to known systems to closely related "perturbed" systems.
- Develop advanced image detector materials to instantly and simultaneously detect one structural (computed tomography) and two functional (position emission tomography and single photon emission tomography) images of medical and life science interest.
- Demonstrate materials capability to allow multimodal imaging system with two orders of magnitude increased scan speed and detection for non-destructive testing and evaluation.
- Develop approaches for exploiting femtosecond laser pulses to generate multi-spectral imaging capable of examining nanostructured materials.
- Develop and exploit new mathematical principles including duality (transformation from an intractable to a tractable task), topology and non-Euclidean geometry to improve general computation capabilities, especially in solid state nanostructured materials.
- Exploit nanotechnology to create a new class of previously inaccessible compositions for optical materials, including IR windows and transparent armor.

	FY 2005	FY 2006	FY 2007
Engineered Bio-Molecular Nano-Devices and Systems	9.790	10.400	10.433

(U) This program seeks to develop and demonstrate engineered bio-molecular nano-scale devices that enable real time observation and analysis of bio-molecular signals, thus enabling single molecule sensitivity with the simultaneous exploitation of the temporal domain (i.e., stochastic sensing). Arrays of such devices will enable an order of magnitude (10 to 100X) reduction in the time required for analysis and identification of known and unknown (engineered) molecules.

(U) Program Plans:

- Engineer hybrid biological/inorganic device architectures that optimize compatibility and information transfer between biological and non-biological materials with single molecule sensitivity.
- Develop new and innovative technologies in the areas of device architecture, design, interconnection, fabrication and integration of organic and inorganic materials to enable measurement of time constants of single molecule events.

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- Develop techniques to perform direct, dynamic, stochastic and combinatorial analysis of bio-molecular signals in order to characterize unique molecular signatures based on such analysis (i.e., automatic recognition) of various biological/chemical targets.

	FY 2005	FY 2006	FY 2007
Spin Dependent Materials and Devices	6.000	12.000	15.000

(U) The major emphasis of this thrust is to provide the theoretical and experimental underpinnings of a new class of semiconductor electronics based on spin degree of freedom of the electron, in addition to (or in place of) the charge. Not only will this class of electronics lead to novel and faster electronic devices, but it will also serve as one of the key technology enablers for quantum communications and quantum computation. In addition, this program will examine other novel classes of materials such as plasmons or Bose-Einstein Condensates that have the potential to provide new capabilities in the quantum regime.

(U) Program Plans:

- Demonstrate a variety of spin related devices such as a room temperature spin light emitting diode (spin LED), a spin transistor with significant gain and magnetic random access memory scaled down into the few nanometer bit size by replacing magnetic field switching with spin momentum transfer switching.
- Develop new storage class memories with 100 – 1000 times the density of MRAM, DRAM or FLASH using magnetic domain walls as the storage media and spin momentum transfer as the read and write protocol.
- Investigate the magnetic and electronic characteristics of surface plasmons for the creation of metal/dielectric interfaces for coupling between photonic and electronic/spin states.
- Demonstrate atom-chip BEC lifetimes of >100ms and quasi-continuous BEC with 2000 atoms/pulse and >20% duty cycle.
- Demonstrate rotationally sensitive atom interferometer using optical readout in magnetic waveguides; establish sensitivity.

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	FY 2005	FY 2006	FY 2007
Spin Electronics	16.200	0.000	0.000

(U) Program Plans:

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

	FY 2005	FY 2006	FY 2007
Molecular Electronics	1.900	0.000	0.000

(U) Program Plans:

– Provided tools for developing molecular electronics technologies to enable construction of electronic circuits at the nanometer-scale for computation. Research focused on the simulation and direct-write fabrication of room temperature single electron transistors using focused ion beam instrumentation.

	FY 2005	FY 2006	FY 2007
Comparative Genomics for National Security Goals	3.000	1.500	0.000

(U) Program Plans:

– Develop new approaches to examine prognostic epidemiology using comparative genomics.

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

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

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

(U) Program Plans:
- Explored more efficient methods for the development of active sensors.

	FY 2005	FY 2006	FY 2007
Advanced Materials for Quantum Computing	0.000	2.650	0.000

(U) Program Plans:
- Development of materials that will enable the instantiation of quantum computing concepts.

	FY 2005	FY 2006	FY 2007
PBO	0.000	1.000	0.000

(U) Program Plans:
- Research into the application of PBO (Polyphenylene benzobisoxazole) in the development of non-flammable and lightweight materials.

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

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research				R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E			
COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	182.815	195.991	242.852	249.651	247.146	245.870	193.870
Intelligent Systems & Software IT-01	12.209	0.000	0.000	0.000	0.000	0.000	0.000
High Performance and Global Scale Systems IT-02	68.909	69.283	82.900	85.000	85.000	85.000	48.000
Information Assurance and Survivability IT-03	48.594	60.964	76.015	79.115	80.977	80.277	65.277
Language Translation IT-04	53.103	65.744	83.937	85.536	81.169	80.593	80.593

(U) Mission Description:

(U) The Computing Systems and Communications Technology program element is budgeted in the applied research budget activity because it is directed toward the application of advanced, innovative computing systems and communications technologies.

(U) The Intelligent Systems and Software project developed new technology for software creation, processing and database management to significantly improve software for systems that produce, store, and analyze information about battlespace operations. It developed fundamentally new techniques for: (1) transforming signals into descriptions of battlespace entities; (2) exchanging information about entities among different systems at both the syntactic and semantic levels; and (3) managing that information exchange as situations and resources change over time.

(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 cost-effective systems; associated software technologies; advanced mobile information technology; and prototype experimental applications critical to defense operations.

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(U) The Information Assurance and Survivability 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 attacked, and will lead to generations of stronger protection, higher performance, and more cost-effective security and survivability solutions scalable to several thousand sites.

(U) The Language Translation project will develop and test powerful new Human Language Technology that will provide critical capabilities for a wide range of national security needs. This technology will enable systems to (a) automatically exploit large volumes of speech and text in multiple languages; (b) revolutionize human-computer interaction via spoken and written English and foreign languages; (c) perform computing and decision-making tasks in stressful, time-sensitive situations; and (d) become active, autonomous agents/assistants to analysts, operators and warfighters by collating, filtering, synthesizing and presenting information in timely and relevant forms.

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

	FY 2005	FY 2006	FY 2007
Previous President's Budget	187.767	198.831	213.723
Current Budget	182.815	195.991	242.852
Total Adjustments	-4.952	-2.840	29.129
Congressional program reductions	-0.146	-2.840	
Congressional increases	0.000		
Reprogrammings	0.000		
SBIR/STTR transfer	-4.806		

(U) Change Summary Explanation:

FY 2005 Decrease reflects DOE transfer for P.L. 108-447 and SBIR/STTR transfer.

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FY 2006	The decrease reflects undistributed reductions for Section 8125 and the 1% reduction for section 3801: Government-wide rescission.
FY 2007	Increase reflects enhancement of the Language Translation project to address technologies to translate documents captured during tactical operations and continue work on two-way tactical speech communications between warfighters and native speakers. The PE increase also addresses funding for Phase III of the High Productivity Computing System (HPCS) program to complete the detailed design, fabrication, integration and demonstration of the first full scale prototypes. New Information Assurance technologies will also be emphasized.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
High Performance and Global Scale Systems IT-02	68.909	69.283	82.900	85.000	85.000	85.000	48.000

(U) Mission Description:

(U) This project develops the computing, networking and associated software technology base required to support future defense and federal needs for computational and information-intensive applications. These technologies will lead to successive generations of more secure, higher performance, and more cost-effective computing systems. The project will also develop critical associated software technologies, advanced mobile information technology, and prototype experimental applications critical to defense operations.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Responsive Computing Architectures	68.909	69.283	82.900

(U) The Responsive Computing Architectures component is bringing much needed flexibility to DoD systems. It is developing integrated computing subsystems that will respond in real time to dramatic changes in mission application requirements and operating constraints based on the mission of the day. Current projects are focused on quality of service, algorithm/application computing diversity and scalable computing efficiency. The technologies being developed here have direct and significant impact for military systems, such as the Land Warrior/Objective Force, ground and airborne autonomous devices, distributed sensors, space sensors and intelligence collection ground systems. The Responsive Computing Architecture component funds the High Productivity Computing Systems program.

(U) The High Productivity Computing Systems (HPCS) program will provide the DoD with significant technology and capability advancements for the national security and industrial communities by filling a critical gap between today’s 1980s-based high performance computing systems and the future promise of quantum computing. This program is targeting high-end, tera-to-petascale computing in medium-to-long-term national security missions where, according to two recent DoD studies, U.S. superiority and security are threatened. The technology development plan is being executed in three phases that will extend to the end of this decade. The three phases are (1) concept study, (2) research

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and development, and (3) prototype development. HPCS will address a number of critical technology barriers over the next decade including: (1) processor/bandwidth performance efficiency; (2) software availability/reliability for large-scale computing systems; (3) integral hardware, software, application robustness; (4) intrusion resistance; (5) run-time software brittleness; (6) time-to-solution; and (7) cost of developing, operating, maintaining, and upgrading DoD national security applications. Through HPCS technology, performance and efficiency for critical national security applications will realize a forty-fold improvement. Early identification of key mission partner users and their high-end computing application requirements, and development of metrics and performance prediction tools will be used throughout the program to assess accomplishment of both technical milestones and adherence to the schedule.

(U) Program Plans:

- Perform a focused industry R&D Engineering Phase II effort that will evaluate, simulate, and prototype the innovative HPC system architectures selected from the Phase I concept studies.
- Release alpha “value based” productivity metrics and benchmarks to guide future program research and development activities.
- Address large system brittleness by exploring hardware and software reliability and fault tolerance capabilities, active application software bug tolerance, and intrusion identification and resistance.
- Evaluate alternative balanced system architectures comprised of processors, memory, interconnects, software, and programming environments that will result in high productivity computing systems.
- Perform a critical technology assessment and prototype engineering readiness review of the Phase II HPCS petascale systems and their viability for implementation in the 20l0 timeframe.
- Perform a down-select from the Phase II R&D commercial participants based on their readiness for prototype development (Phase III); their ability to address the government’s HPC needs in the 2010-2011 timeframe, and their commercial viability.
- Initiate research prototype development (Phase III) of a high-end petascale computing system with improved time-to-solution characteristics, in collaboration with other government agencies.
- Implement applied high productivity language software and intelligent file system research to support the revitalization of high-end computing.

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(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Information Assurance and Survivability IT-03	48.594	60.964	76.015	79.115	80.977	80.277	65.277

(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 attacked. The technologies will also 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 by all the projects within this program element, and those in the Command, Control, and Communications program element (PE 0603760E), the Network-Centric Warfare Technology program element (PE 0603764E), the Sensor Technology program element (PE 0603767E), the Guidance Technology program element (PE 0603768E), and other programs that satisfy defense requirements for secure, survivable, and network centric systems.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Next Generation Optical Networks	7.521	6.754	6.463

(U) The Next Generation Optical Networks program will revolutionize the operation, performance, security, and survivability of the United States' critical inter-networking system by leveraging technology developed in DARPA photonics component and secure networking programs. These goals will be accomplished through a transformation in fundamental networking concepts that form the foundation upon which future inter-networking hardware, architecture, protocols and applications will be built. Key technical enablers that will be developed in this thrust include: (1) the elimination of data-flow bottlenecks and the enhancement of network scalability through the creation of optical network hardware that minimizes the occurrence of need for optical-to-electrical-to-optical conversions; (2) greatly increased network capacity through the use of more efficient fiber-optical transmission techniques; (3) network management tools that guarantee optimization of high density wavelength-division-multiplexed optical channels, such as those provided by wavelength division multiplexing; (4) creation of a new class of protocols that permit the

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cross-layer communications needed to support quality-of-service requirements of high-priority national defense applications; and (5) demonstration of novel concepts in intelligent and cognitive switched based networks. This effort will deliver the high-performance inter-networking capabilities needed for development of applications such as distributed and network based command and control, intelligence analysis, predictive logistics management, simulation and scenario enhanced decision-making support for real-time combat operations, and assured operation of critical U.S. networking functions when faced with severe physical layer attack. These network-based functions will support the real-time, fast-reaction operations of senior leadership, major commands and field units.

(U) An important initial component of this program, the Tactical Fiber-Optical Network effort will make it possible for the U.S. military to create a rapidly deployable, self-healing, tactical wavelength-division-multiplexed (WDM) fiber-optical network that can provide substantial communications capability to command centers deployed in somewhat mature areas of hostility. Key capabilities that will be enabled by this program include: (1) the elimination of power needs in the core of the network through the design and fabrication of passive wavelength-routing nodes that will allow the switching functions to be done via tunable optical transmitters and receivers (transceivers) at the edge of the network; (2) enhanced network survivability through a suitable highly connected network topology leveraging a fast-restoration protocol capable of rapid recovery from multiple network node and link failures; and (3) extended geographical coverage of the network to hundreds of kilometers, without requiring additional power at the core. In addition, protocols will be developed to enable the connection of this network to tactical wireless networks as well as to existing fixed legacy networks. The program will also include the development of techniques to realize ruggedized network nodes and interconnecting fiber cables, which are to be buried in the ground or in riverbeds or other waterways.

(U) A companion program, the Millimeter Wave Networks project, explored new technology to make the upper millimeter wave (MMW) region affordable for proliferated use in an operational environment. This project investigated the unique characteristics of the 60GHz band, which attenuates radio signals very rapidly due to absorption, to develop network devices that can transmit the reasonably high levels of power required for high data rates, and still be undetectable at a distance from the network.

(U) Program Plans:

- Next Generation Optical Networks
  - Create an all-optical hardware design and fabrication to enable regeneration, wavelength switching and sub-wavelength grooming.
  - Develop and demonstrate an efficient fiber-optical transmission technique to enable several-fold increase in fiber capacity.

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  - Develop switch architecture design and signaling protocols for zero-apparent-jitter, low-latency, real-time applications.
  - Develop national testbed hardware specification, local area to wide area network integration, with data-format independence.
  - Develop protocols for physical layer-to-application layer connectivity and routing algorithms for optically switched networks.
  - Demonstrate the ability to manage frequency and enforce low probability of detection limits.
  - Enable the interface between optically switched backbone networks and conventional networks.

- Tactical Fiber-Optical Network
  - Create a suitable architecture for a passive, WDM fiber-optical network with high connectivity for increased reliability.
  - Develop a set of passive, wavelength-routing nodes that can enable the realization of this architecture.
  - Develop a wavelength plan for interconnecting client devices with tunable optical transceivers placed at the edge of the network.
  - Develop a protocol for rapid restoration from multiple network node and link failures through re-tuning the optical transceivers.
  - Conduct an analysis to estimate the resulting network reliability and survivability under various failure scenarios.
  - Demonstrate the ability to interconnect client devices with a wide range of analog and digital signal formats and protocols.
  - Devise appropriate protocols to enable the integration of the network with tactical wireless networks.
  - Develop protocols and interfaces to enable connecting this network to existing legacy networks.
  - Develop techniques to realize ruggedized network nodes and fiber cables.
  - Build and test a network testbed that is representative of a network suitable for one or more target aerospace platforms.

- Millimeter Wave Networks
  - Validated that photonics-based modem and RF sources are orders of magnitude simpler than conventional RF.
  - Determined that the upper millimeter wave region offers increased RF power scaling due to low combining loss which can allow almost unbounded bandwidth.

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	FY 2005	FY 2006	FY 2007
Dynamic Quarantine of Computer-Based Worms	14.807	18.643	19.671

(U) The goal of the Dynamic Quarantine of Computer-Based Worms program is to develop defenses for U.S. military networks against large-scale malicious code attacks such as computer-based worms. As the U.S. military pushes forward with network-centric warfare, terrorists and other nation-states are likely to develop and employ malicious code to impede our ability to fight efficiently and effectively. This program will develop the capability to automatically detect and respond to computer-based worm attacks against military networks, provide advanced warning to other DoD enterprise networks, provide rapid recovery of infected systems, study and determine the worm's propagation and provide off-line rapid response forensic analysis of malicious code to identify its capabilities, and future behavior. Additionally, the program will investigate technologies for defense against cyber attacks on mobile ad hoc network (MANET) systems. This effort will develop defenses that can sense failures and attacks on military tactical wireless networks and auto-reconfigure in real-time to provide continuous service of mission-critical activities. This program will develop technology to ensure wireless mobile network centric warfare systems are able to fulfill their mission in spite of runtime hardware/software failures and cyber attacks such as computer worms unleashed on MANETs. This program will develop technology to reconfigure the network, nodes, and platforms for optimal mission execution as a result of changes that may occur in the trustworthiness of the network.

(U) Program Plans:

- Developed and tested automatic detection and quarantine mechanisms.
- Developed and transitioned off-line malicious code analysis capabilities.
- Test auto-quarantine capabilities against more sophisticated threats.
- Develop emulated wireless mobility testbed.
- Develop host and network-based detection and quarantine sensors/actuators for MANET systems.
- Develop application re-provisioning services for failed nodes.
- Verify integrated system capabilities.

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	FY 2005	FY 2006	FY 2007
Trustworthy Systems	8.551	9.757	10.058

(U) The goal of the Trustworthy Systems program is to provide foundational trustworthy computer platforms for DoD computing systems. This program seeks to develop technologies such as novel computer processing architectures, hardware, firmware, or microkernels that will guarantee the security and integrity of data processed for secure applications. The military utility of the technology would be to provide high degree of assurance that software systems procured by DoD cannot compromise the DoD missions they support even when compromised by Trojan horse software, or just plain buggy software. Transition targets include weapons platforms, flight control systems, and enterprise software systems. The transition customers are Joint Task Force (JTF)-Global Network Operations and the DoD Enterprise Security Steering Group (ESSG) for providing DoD enterprise wide information assurance solutions.

(U) Initially, an Information Assurance (IA) Transition effort in this project will identify, develop, and transition key information assurance research technologies to DoD networks, filling gaps in commercial off-the-shelf (COTS) tool coverage. Specifically, previously-funded DoD research technologies will be identified, matured, evaluated, and deployed on select DoD networks as a testbed for developmental integration testing. This program provides a framework for advocates of other technologies to be similarly considered for deployment to DoD networks. The desired final output of the program is a more secure DoD network, providing improved protection against current and future threats.

(U) Program Plans:

- Trustworthy Systems
  - Develop hardware, firmware, and microkernel architectures as necessary to provide foundational security for operating systems and applications.
  - Develop tools to find vulnerabilities in complex open source software.
  - Develop scalable formal methods to formally verify complex hardware/software.

- Information Assurance (IA) Transition
  - Mature the technologies to the point they can be operationally tested.

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-- Test and evaluate secure hardware designs, software architectures, and code assessment technologies.
-- Deploy technologies on pilot network.
-- Identify key IA technologies for transition.

	FY 2005	FY 2006	FY 2007
DARPA Future Information Assurance Initiatives	2.009	4.150	5.603

(U) The Department's vision for the future includes comprehensive knowledge of the battlespace and the ability to fight wars with information technology that enables remote C^4ISR operations. Sophisticated computing capabilities like those available in current desktop workstation and server systems are moving to mobile wireless embedded systems that communicate over low bandwidth self-organizing tactical networks often with low-powered devices. Concurrent with the advanced computing capability will be security and other trustworthiness challenges in the systems that the future U.S. military will be heavily dependent upon during battle. With the increased U.S. military dependence on information technology, the ability to maintain battlefield superiority requires control of our information systems against increasingly sophisticated adversaries employing computer network attack. With foreign production of information technology increasing, and adversaries seeking to use the asymmetric leverage of cyber warfare as the Achilles' heel of current and future U.S. military systems; the U.S. military must have the ability to withstand, operate through, and counter increasingly lethal cyber attacks, while reducing the manpower required. The DARPA Future Information Assurance Initiatives will identify promising technologies to continue to push the state of the art and pursue transition opportunities to promote adoption by the military services. Other distinct programs within this project will be created to pursue promising technologies as they are identified for further focused development.

(U) Program Plans:
- Develop automatic techniques to modify computer applications to add information assurance properties e.g. confidentiality, authentication, and others.
- Develop the ability of individual hosts (end-points) to learn essential characteristics about the network path between themselves and their transmission partners.

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– Develop the ability to protect the core signaling and control of converged networks running voice over IP (VOIP), wireless, and voice, and data networks in enterprise telecommunications.
– Identify and authenticate hosts on the network with a follow-on goal of allowing these hosts to query the network to discover the network's operating attributes.
– Develop a family of distributed, autonomous firewalls that work together as required to deal with asymmetric traffic on wide area networks.
– Develop a wireless protocol that securely provides location, authentication, and communications in a practical manner.
– Investigate new approaches to network security that scale with increased data rates and address spaces of future networks.

	FY 2005	FY 2006	FY 2007
Control Plane	3.597	5.752	7.956

(U) The Control Plane Program will improve end-to-end network performance between the Continental United States (CONUS) operating base and forward deployed tactical units. Control Plane seeks to develop the ability for individual hosts (end-points) to learn essential characteristics about the network, allowing the hosts to shape the network in a way that optimizes network loading, prioritizes traffic, and creates communities of interest among nodes in large networks. Additionally, when multiple network paths are available, hosts will be able to choose the best path/community or simultaneously transmit over multiple paths/communities. This technology will support the Defense Department's Global Information Grid concept of operations.

(U) Program Plans:
– Develop mechanisms to improve end-to-end wide-area network performance between the Continental United States (CONUS) operating base and forward deployed tactical units.
– Develop the ability of individual hosts (end-points) to learn essential characteristics about the network path between themselves and their transmission partners through network query protocols.
– Investigate authentication protocols for secure transmission of network performance information.

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- Develop the ability of hosts to learn about more than one possible transmission path, other hosts' abilities and purpose, and form communities of interest which suits their collective needs best.
- Develop the ability of hosts to simultaneously use multiple network paths for the same data transmission with the same partner, increasing communications speed and reliability.

	FY 2005	FY 2006	FY 2007
Wide Area Network (WAN) Monitoring	1.267	2.408	4.300

(U) The Wide Area Network (WAN) Monitoring effort seeks to develop distributed network monitoring capabilities and devices that can be used to identify, characterize, enable, optimize and protect the WANs that compose the Global Information Grid (GIG). This program will develop advanced capabilities to monitor the WANs that will comprise the GIG in to detect information flows that are indicative of malicious behavior, routing problems, or compromised mission capability. Goals include improved detection and false-alarm performance over conventional intrusion detection systems and scalability to the larger networks. This technology will support the Department of Defense's Global Information Grid Information Assurance technical framework.

(U) Program Plans:
- Develop algorithms representing that quickly characterize various host's security configurations, identity, and classification as well as measure the type and quantity of information exchange.
- Develop high-throughput hardware to implement the algorithms at the sensor layer.
- Develop low-latency networks to collect the information.
- Develop high-speed analyzers to assimilate the data and detect perturbations.
- Integrate and test components in a fully functional configuration.

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	FY 2005	FY 2006	FY 2007
Spread Spectrum Networking	0.000	0.000	2.900

(U) Spread spectrum communication technology will significantly improve security against a variety of network attacks and identification profiles by spreading energy over a broad bandwidth, thereby providing an adversary with a signal which is both difficult to detect, as well as difficult to jam without using significant resources. This program expands these same goals, by addressing not just the physical layer but also the entire network stack. Similar to frequency-hopping spread spectrum, the approach of this program is to develop and demonstrate algorithms that provide hopping between IP addresses and then expanding to hopping between different permutations of layer 1-3 protocols. The utility is to provide significantly improved security against a variety of network attack and identification profiles.

(U) Program Plans:

- Determine the most effective cross layer spreading techniques through analysis and simulation.
- Implement these techniques on relevant platforms.
- Demonstrate the effectiveness of these techniques against network attack.

	FY 2005	FY 2006	FY 2007
Control-Based Mobile Ad-Hoc Networks	0.000	4.500	6.099

(U) An outgrowth of the Trustworthy Systems and the DARPA Future Information Assurance Initiatives, the Control-Based Mobile Ad-Hoc Networks (CBMANET) program will develop an adaptive networking capability that dramatically improves performance and reduces life-threatening communication failures in complex communication networks. In order to develop this new capability, the initial focus is on tactical mobile ad-hoc networks (MANETs). MANETs are composed of interdependent nodes based on interdependent system layers. Each node exposes tens to hundreds of configurable parameters that must be continuously adapted due to variable tactical factors such as mission profile, phase, force structure, enemy activity, and environmental conditions. The complexity of this high-dimensional, adaptive, constrained, distributed network configuration problem is overwhelming to human operators and designers and has root causes in the historically wireline-oriented networking

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paradigms. Today's commercial trends are not aimed at supporting the DoD's extreme deployments or unique applications. This program will take on the ambitious goal of researching a novel protocol stack that supports integrated optimization and control of all network layers simultaneously. Key technical challenges include scalable design, stability, and convergence. These challenges are particularly difficult in a distributed setting with partial and uncertain information, high communications overhead, and high probability of link failure. To address this problem, the CBMANET program will exploit recent optimization-theoretic breakthroughs, recent information-theoretic breakthroughs, and comprehensive cross-layer design to develop a network stack from first principles with specific attention to support for DOD applications such as multicast voice and situation awareness.

(U) Program Plans:
- Design and develop a novel protocol architecture from first principles in information theory and optimization theory.
- Design and demonstrate protocols based on network coding that vastly improve performance in extreme conditions.
- Design and demonstrate cross-layer protocols and adaptive control capabilities to drive resource allocation more efficiently.
- Design novel control interfaces to support DOD-relevant applications such as multicast and situation awareness.
- Design appropriate interfaces between the novel network stack and the physical radio platforms to support cross-layer optimization.
- Perform quantitative analysis and trade studies to understand the degree of performance offered by the novel network stack.

	FY 2005	FY 2006	FY 2007
Security-Aware Systems	6.103	9.000	12.965

(U) Today's military software systems are brittle in the face of changing requirements. They are vulnerable to skilled attackers who develop creative and unpredictable strategies, and are increasingly dependent on software produced in and/or "outsourced" to potentially hostile nations. Misconfiguration accounts for most security failures in internet services and poses a serious risk to military systems. This program will develop security aware systems that will avoid brittleness and vulnerability, due to their ability to reason about their own security attributes, capabilities and functions with respect to specific mission needs. These systems will also dynamically adapt to provide desired levels of service while minimizing risk and providing coherent explanations of the relative safety of service level alternatives. These systems will bolster the reliability and security of critical open source software systems by reducing vulnerabilities and logic errors, and providing state-of-the-art software analysis techniques augmented with cognitive decision-making techniques with the ultimate goal of applying these systems on to the Global Information Grid.

(U) This Security-Aware Systems thrust was previously budgeted in the DARPA PE 0602304E, Project COG-01. It has been enhanced with technologies and approaches developed under the Trustworthy Systems, Asymmetric Flow Monitoring and the DARPA Future Information Assurance Initiatives, programs within this project. The Security-Aware Systems thrust will also explore practical advanced software engineering technology for building flexible systems that will allow new features to be added via "interposition" between existing features, with guaranteed levels of reliability and security. Cognitive and automated software analysis techniques will screen outsourced software both for quality lapses and unauthorized functionality to assure the outsourced code performs as expected. Strategies for intelligently adapting complex system configurations in response to operator action will be developed. Cognitive reconfiguration technology will infer the user's legitimate goals and adapt configurations to rapidly meet those goals with a minimal impact on security and longer-term objectives. The Security-Aware Systems thrust encompasses the Application Communities (AC) program together with several supporting research initiatives.

(U) The Application Communities (AC) program will leverage the research conducted under DARPA's information assurance programs to create a new generation of self-defending software that automatically responds to threats, and provide a comprehensive picture of security properties and current status displayed at multiple levels of abstraction and formality. This capability will bring intelligent security adaptation to DoD systems and make security properties and status more apparent to decision makers, thus increasing the speed and confidence with which military systems can be securely and dynamically reconfigured, particularly under stressful conditions. AC technology will enable collections of similar systems to collaboratively generate a shared awareness of security vulnerabilities, vulnerability mitigation strategies, and early warnings of attack. AC will revolutionize the security of military information systems and reduce the threat from stealth attacks (where attackers take control of systems undetected).

(U) Research initiatives related to vulnerabilities, missions and threats in computer abstract-model reasoning will enable systems to create a prioritized list of threats and analyze the hypotheses about threats in the context of system development and deployment. The resulting technology will enable current systems to generate vulnerability reports ranked by probable impact of a failure/attack on the mission. In addition, technology that results in a multi-level network operating system capable of controlling the flow of classified information will prevent unauthorized leakage through computer systems, and provide planners and intelligence analysts safe, simultaneous, and convenient access to classified and unclassified information.

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(U) Program Plans:

– Develop techniques to collaboratively diagnose and respond to problems (e.g., attacks or failures that threaten a mission) in groups of military systems.
– Demonstrate automated techniques for reasoning about and understanding the security-relevant interactions between software components of military systems.
– Develop techniques to summarize security policy and status so the descriptions produced by AC can be understood without omitting critical details.
– Augment current techniques to construct a framework for developing high-assurance behavioral specifications (including security policies). Formulate a unified knowledge base to represent the properties and capabilities of disparate security mechanisms.
– Develop static and dynamic source code analysis techniques (e.g., data- and control-flow-based techniques, model-checking, strong typing) to relate software module structures and runtime state with the representation of security properties/configurations.
– Demonstrate self-explanation techniques in which systems explain their critical security properties and status in a manner that is understandable to a variety of managing software components and human operators.
– Develop test and validation regimes to assess the protection mechanisms of security products and certify protection to quantifiable levels based on a scientific rationale.
– Develop measures to quantitatively characterize various dimensions of security (availability, integrity, confidentiality, authentication, and non-repudiation), fault tolerance, and intrusion tolerance and demonstrate the theory’s relevance by applying it to a realistic exemplar system.
– Develop techniques for practical construction of extensible software and analysis techniques for predicting the effects of new functionality inserted into a system.
– Develop a theory of code to formalize the properties of interposition and stimulate a new wave of software reliability and productivity improvement.
– Demonstrate cognitive security analysis of complex multi-component software systems.
– Develop an ontology of system and security configuration settings and ontology-based techniques that infer and express operator goals.
– Build information flow tracking and dynamically-reconfigurable event interposition into modeling techniques and their supporting tools.

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- Develop reasoning techniques to evaluate the impact of negative scenarios on a system design and anticipated mission scenarios.
- Develop network switches that provably control information flows according to a specified policy.
- Develop ubiquitous, intelligent software agents that learn and respond to attacks on Global Information Grid infrastructure scale.
- Integrate developed technologies into the Global Information Grid.

	FY 2005	FY 2006	FY 2007
Fault Tolerant Networks	1.000	0.000	0.000

(U) The primary goal of the Fault Tolerant Networks program has been to develop technologies that provide for continuous and correct network operation even when attacks are successful. By developing reliable, ad-hoc, and adaptive networking protocols that allow for communications between peers during conditions of known or suspected faults or attacks in wide-area networks, this program has developed technologies to dramatically improve communications across the network. This program was designed to seek a number of different networking protocols and technologies to improve network security and provide quantitative statistical metrics that allow for the objective evaluation of network performance when fault condition exists or attacks are on-going or suspected.

(U) Program Plans:

- Developed a unified model for multi-path communication.
- Developed protocols for reliably communicating between peers in ad-hoc networks and adaptive multi-path forwarding protocols for tolerating and adapting to faults in wide-area networks.
- Demonstrated attack profiling and filtering algorithms that discard a high percentage of Distributed Denial of Service (DDoS) traffic and a low percentage of non-DDoS traffic.
- Extended an overlay network prototype to integrate boundary security, enforcing overlay separation and preventing leakage of traffic onto the base network.
- Demonstrated statistical measures that are both efficient and effective at detecting traffic that contributes to a DDoS attack that originates multiple network “hops” back from the attack target.

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- Implemented and evaluated distributed queuing in prototype router hardware while continuing fundamental studies of distributed queuing algorithms, with a focus on algorithms that support reservation-oriented traffic.
- Developed tools for measuring and communicating the structure of network topologies in both wide-area and mobile environments and for measuring underlying latencies, service times, and characteristics that constrain the best possible network availability solutions.

	FY 2005	FY 2006	FY 2007
Dynamic Coalitions	1.000	0.000	0.000

(U) The Dynamic Coalitions program has developed technologies that allow the formation of partnerships between and across organizations that are seeking joint collaboration to provide secure networking communications, improve policy management and group communications, and provide for the improved security of infrastructure services and data sharing. Given that future U.S. military operations will be increasingly "joint," involving multiple branches of the U.S. Armed Forces and, potentially allied or other coalition forces, secure and accessible communication will be critical for future war-fighting scenarios outlined in Joint Vision 2020. This effort has leveraged recent advancements in wireless networking technologies by investigating those technologies that can migrate coalition information assurance tools from servers to gateway radios, thereby allowing such functionality to spread throughout the coalition. The most promising technologies sought under this program are being tested in operationally relevant experiments with U.S. warfighters in DARPA's Partners in Experimentation program which is also budgeted in this project.

(U) Program Plans:

- Developed a new formalism for application level policies to accommodate new aspects of policy that do not manifest at the network layer, such as access control mechanisms.
- Developed specific technology to enable multi-level network management and multi-level message passing.
- Completed the implementation of the surrogate trust negotiation architecture for supporting trust negotiation in a wireless environment.

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- Experimentally proved that architectures that incorporate reusable tickets or tokens can eliminate the need for repetitive, heavyweight trust negotiations between protected resources within a security domain without compromising the security of the overall system.
- Demonstrated adaptors to a policy engine for a set of real networking, monitoring and control technologies including: network management tools; commercial firewalls; and application specific entities such as web servers.

	FY 2005	FY 2006	FY 2007
Partners in Experimentation	2.739	0.000	0.000

(U) The Partners in Experimentation program conducted security technology experimentation with operational military and coalition partners. As part of this effort, the program developed relationships with partners that led to multi-application information sharing, as well as improving interoperability between the participating partners. Such experimentation also led to the development of technologies for distributed denial of service countermeasures and encryption techniques to secure email across multiple organizations working collaboratively. Operational experimentation provided valuable feedback to the security technology research and development process; demonstrated the benefits of advanced technology; and accelerated technology transition.

(U) Program Plans:

- Transitioned Identity Based Encryption to the United States Northern Command (USNORTHCOM) for communicating sensitive but unclassified data between Department of Defense and local, state and other Federal non-DoD agencies as well as non-governmental agencies.
- Demonstrated identity-based encryption techniques to secure email in a multi-organization collaborative environment.
- Demonstrated secure group communication capability for informal trust relationships.
- Provided the capability for cross-domain information sharing for an interoperability demonstration.
- Constructed and demonstrated a trusted patch management system as well as an Information Assurance Vulnerability Assessment (IAVA) compliance checking capability.
- Evaluated performance and scalability of lab-proven anomaly detection techniques for intrusion detection in real-world, high-volume environments.

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– Demonstrated network monitoring and Distributed Denial of Service (DDoS) countermeasures.
– Demonstrated multi-application cross-domain information sharing capability.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Language Translation IT-04	53.103	65.744	83.937	85.536	81.169	80.593	80.593

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

(U) This project will develop and test powerful new technology for processing human languages that will provide critical capabilities for a wide range of national security needs. This technology will enable systems to (a) automatically exploit large volumes of speech and text in multiple languages; (b) revolutionize human-computer interaction via spoken and written English and foreign languages; (c) perform computing and decision-making tasks in stressful, time-sensitive situations; and (d) autonomously collate, filter, synthesize and present relevant information in timely and relevant forms.

(U) <u>Program Accomplishments/Planned Programs:</u>

	FY 2005	FY 2006	FY 2007
Situation Presentation and Interaction	10.900	16.373	20.837

(U) The Spoken Language Communication and Translation System for Tactical Use (TRANSTAC) program will develop technologies that enable robust spontaneous two-way tactical speech communications between our warfighters and native speakers. The program addresses the issues surrounding the rapid deployment of new languages, especially, low-resource languages and dialects. TRANSTAC will build on existing speech translation platforms developed in the previous Compact Aids for Speech Translation program to create a rapidly deployable language tool that will meet the military's language translation needs. For example, the program will add a two-way translation capability and will include Arabic dialects spoken in Iraq (the current Phraselator uses only Modern Standard Arabic).

(U) Program plans:
- Perform mission needs analysis and aggressive initial language data collection.
- Develop and evaluate a two-way spoken English-Iraqi Arabic communication device for Stability and Support Operations and tactical missions.

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– Demonstrate an initial two-way Iraqi system.
– Develop new two-way translation software technologies for insertion into and enhancement of the two-way Iraqi systems.
– Develop techniques for the system to learn and adapt in the field.
– Perform continuous in-field language data collection.

	FY 2005	FY 2006	FY 2007
Automated Speech and Text Exploitation in Multiple Languages	42.203	49.371	63.100

(U) This thrust includes the Global Autonomous Language Exploitation (GALE) program which leverages technologies developed under two predecessor programs: Translingual Information Detection, Extraction and Summarization (TIDES), a program that developed new capabilities for translation (converting foreign language material to English), detection (finding or discovering needed information, e.g. topics), extraction (pulling out key information including entities and relations), and summarization (substantially shortening what a user must read); and Effective, Affordable, Reusable Speech-To-Text (EARS), a program that created transcription (speech-to-text) technology for broadcasts, telephone conversations and multiparty speech that were either stand alone products or inputs to TIDES technologies.

- Global Autonomous Language Exploitation (GALE) will revolutionize the exploitation of both speech and text in multiple languages (which is currently slow, labor-intensive, and limited) by developing core enabling technologies and end-to-end systems for insertion into a series of high-impact military and intelligence operational settings. GALE will substantially improve upon and exploit capabilities developed under TIDES, build upon the successes of both TIDES and EARS, and emphasize the creation of a systems framework for integrating the component language processing technologies, evaluating them based on their utility in various end-user tasks. GALE technology will enable machines to convert and distill enormous volumes of streaming speech and text in many languages to provide critical intelligence. Specifically, the GALE technologies will provide an English translation of foreign speech and text into English text with extremely high accuracy (95%). GALE technologies will also distill text from both the English sources and the output of the translation engines to pinpoint the concise portions of documents that are relevant to military users, eliminating the need to browse through huge volumes of information. This program will research speech processing technology that has the potential to address spoken utterances in hostile, noisy environments.

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- A follow-on program, Multilingual Automatic Document Classification, Analysis and Translation (MADCAT), will address the recurring military problem of understanding the content of documents captured during tactical operations. These documents often contain machine printed and handwritten text in various combinations and orientations in one or more languages. MADCAT devices would enable soldiers to convert these documents to readable English in the field. Such documents contain perishable information and timely translation is critical. Currently, the military does not have the resources to meet this critical demand. The MADCAT program will substantially improve document analysis and OCR/OHR (optical character recognition/optical handwriting recognition) technology, integrate it tightly with translation technology, and assemble technology demonstration prototypes for field trials.

(U) Program Plans:

- Transition technologies developed by TIDES and EARS into high-impact military systems and intelligence operational centers including CENTCOM, SOCOM and MARFORPAC.
- Develop methods for porting TIDES technology to new languages.
- Leverage TIDES and EARS research to develop technology to convert huge volumes of streaming speech and text in multiple languages into English text by transcribing English speech while simultaneously transcribing and translating foreign speech and text.
- Develop technology to distill critical intelligence from English text by improving information retrieval, extraction and information tracking techniques.
- Design and document an architecture based on the Unstructured Information Management Architecture (UIMA) that was extended and enhanced for GALE.
- Identify workflows of all processing engines and provide integration of these workflows on top of the architectural foundation.
- Architecturally support the creation of components that combine the output of multiple machine translation engines.
- Develop an integrated approach where the problem is viewed mathematically as a single system, with foreign speech/text as input and English text and distilled information as output.
- Develop methods to optimize the parameters of speech-to-text acoustic models such that transcription errors are minimized on the training data.
- Implement an integrated search of speech-to-text transcription and machine translation.
- Develop discriminative training algorithms to optimize word alignment and translation quality.
- Develop technology to enable processing of speech uttered in hostile, noisy environments.

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- – Develop technology for robust speech recognition with noise suppression and multi-input and output blind source separation.
- – Develop algorithms to predict the syntactic structure and propositional content of text.
- – Develop technology to convert captured documents into readable and searchable English.
- – Improve and exploit document segmentation, language and type identification, and script and ideographic character recognition technology.
- – Insert GALE technologies and systems into high-impact military and intelligence operations centers.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	145.833	163.430	220.085	227.604	235.032	247.494	246.243
Cognitive Systems Computing Foundations COG-01	19.800	26.678	37.635	40.184	42.651	43.751	43.751
Cognitive Computing COG-02	85.187	88.931	121.263	126.194	130.630	139.992	140.741
Collective Cognitive Systems and Interfaces COG-03	40.846	47.821	61.187	61.226	61.751	63.751	61.751

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

(U) The Cognitive Computing Systems program element is budgeted in the Applied Research budget activity because it is developing the next revolution in computing and information processing. The technology will allow computational systems to have reasoning and learning capabilities and levels of autonomy far beyond those of today's systems. With the ability to reason, learn and adapt, and with facilities for self-awareness, these will literally be systems that know what they are doing, enabling new levels of capability and powerful new applications.

(U) Cognitive Systems are different from conventional computing systems in that they manipulate rich structured representations of their knowledge, learn from experience and add to their store of knowledge, mix symbolic logical knowledge with uncertain and probabilistic information, allow reflective self-aware inference, and support the transition of perceptual (e.g., visual, auditory) data to symbolic information. These capabilities are not well matched to the architectures that support more conventional computing. The Cognitive Systems Computing Foundation project is developing the tools and architecture necessary to support the cognitive computing revolution.

(U) The Cognitive Computing project will develop core technologies that enable computing systems to learn, reason and apply knowledge gained through experience, and respond intelligently to things that have not been previously encountered. These technologies will lead to systems demonstrating increased self-reliance, self-adaptive reconfiguration, intelligent negotiation, cooperative behavior and survivability with reduced human intervention.

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(U) The Collective Cognitive Systems and Interfaces project will dramatically improve warfighter and commander effectiveness by developing revolutionary methods for users to interact with and direct cognitive systems (including the physical sensors and effectors). This research will improve the interaction among multiple large-scale cognitive systems, in support of the user's objectives. Specifically, this project will develop technologies to enable systems to detect and assess the user's cognitive state and adapt to optimize the user's understanding and effectiveness.

(U) Program Change Summary: *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	149.782	200.799	241.006
Current Budget	145.833	163.430	220.085
Total Adjustments	-3.949	-37.369	-20.921
Congressional program reductions	-0.115	-37.369	
Congressional increases	0.000		
Reprogrammings	0.000		
SBIR/STTR transfer	-3.834		

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

FY 2005	The decrease reflects DOE transfer for P.L. 108-447 and SBIR/STTR transfer.
FY 2006	The decrease reflects the $35M congressional cut to Project COG-02; Cognitive Computing and undistributed reductions for Section 8125 and 1% reduction for Section 3803: Government-wide rescission.
FY 2007	Decrease reflects rephasing of efforts in response to FY 2006 congressional action.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Cognitive Systems Foundations COG-01	19.800	26.678	37.635	40.184	42.651	43.751	43.751

(U) Mission Description:

(U) Cognitive Systems are different from conventional computing systems in that they draw inferences from rich structured representations of their knowledge, learn from experience, combine symbolic logical knowledge with uncertain and probabilistic information, allow reflective reasoning, and support the integration of perceptual (e.g., visual, auditory) data with symbolic information. The next generation of computer systems will rely upon reasoning, learning, and self-monitoring to handle increasingly complex tasks. These systems will be advisable, adaptable and able to cope with surprise. As a result, these novel forms of computation will revolutionize future military systems. The Cognitive Systems Foundations project will develop the necessary foundational hardware architectures and software methods to facilitate learning and inference capabilities that are crucial to intelligent computing. These new computing foundations will help us move far beyond today's standard Von Neumann computing model.

(U) Cognitive Systems for military applications must be robust and resistant to both attacks and system failures. The military faces aggressive and agile threats that have sufficient technical resources to mount sophisticated attacks using easily accessible commercial information systems. The pervasive nature of both the threat and its means drives the need for systems to dynamically adapt, collect and assimilate large quantities of systems operation data, and remain robust even under aggressive attacks or failure conditions. Cognitive Systems Foundations will enable future computer systems to be more responsible for their own configuration, monitoring, protection and restoration to full functional and performance capabilities after an attack or failure.

(U) Overall this project seeks to make fundamental scientific improvements in our understanding of, and ability to, create more intelligent information and computing systems. Transition goals include next-generation network-centric systems and platform-specific information collection and processing systems in space, air, sea and land.

(U) The Security Aware Systems thrust previously budgeted in this project has been moved to PE 0602303E, Project IT-03 as it is more closely aligned with the programs in the Information Assurance and Survivability Project.
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(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Architectures for Cognitive Information Processing	9.895	14.043	19.000

(U) The Architectures for Cognitive Information Processing (ACIP) program is developing a new class of processing approaches, algorithms and architectures to efficiently enable and implement cognitive information processing. ACIP will develop the micro-architecture concepts, framework, and development environments that will provide the basis for and enable innovative and efficient cognitive information processing. Current intelligent processing implementations depend on the use of existing numerically-based architectures and/or standard software architectures, and are therefore built on algorithms and processing foundations that are potentially ill-suited to cognitive tasks. Architectures that more directly mirror the symbolic reasoning, learning, and perception functions of a cognitive system are needed to enable major advances in this area. The ACIP program will establish core processing capabilities that significantly advance the state of the art at all implementation processing levels – modules, systems, and underlying cognitive processing approaches, algorithms and architectures. In order to focus and establish context for the ACIP program, ACIP will pursue in-context DoD focused mission areas for the development of new data processing concepts. ACIP will develop implementations that span the areas of perception, reasoning and representation, learning, communication and interaction. The ACIP program will enable new classes of cognitive information processing applications that move the U.S. dramatically toward the overall goal of creating computer systems that know what they are doing.

(U) Program Plans:
- Selected innovative computer architecture(s) and in-context applications for cognitive architecture implementations, demonstrations and developments.
- Develop, simulate and evaluate innovative cognitive computer architecture concepts and evaluate in-context cognitive application baselines based on current approaches and “best-possible” implementations using existing processor architectures.
- Characterize the role of reflective reasoning in a cognitive system that reacts effectively to stimuli and uses deliberation to plan and solve problems.
- Explore a first-generation framework supporting cognitive approaches, algorithm development and architectural evaluation.

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– Develop, prototype, and demonstrate innovative cognitive computer architectures that will provide at least a 100X improvement over today's systems and a real-time adaptation for DoD cognitive applications.
– Develop a comprehensive digital repository architecture to enable ubiquitous access from multiple devices while providing secure, effective, document sharing.
– Develop a prototype system with military applicability that could accommodate thousands of users and further facilitate an open, extensible, and vender-independent architecture.

	FY 2005	FY 2006	FY 2007
Self-Regenerative Systems	9.905	12.635	18.635

(U) The Self-Regenerative Systems (SRS) program will design, develop, demonstrate and validate architectures, tools, and techniques for fielding systems capable of adapting to novel threats, unanticipated workloads and evolving system configurations. The technology development phase of this program will employ innovative techniques like biologically-inspired diversity, cognitive immunity and healing, granular and scalable redundancy, and higher-level functions such as reasoning, reflection and learning. These technologies will make critical future information systems more robust, survivable and trustworthy. The SRS program will also develop technologies to mitigate the insider threat. The systems phase of the program will combine the SRS technology foundations in an exemplar military system that learns, regenerates itself, and automatically improves its ability to deliver critical services over time.

(U) SRS-enabled systems will be able to reconstitute their full functional and performance capabilities after experiencing an accidental component failure, software error, or even an intentional cyber-attack. SRS systems will show a positive trend in reliability, actually exceeding initial operating capability and approaching a theoretical optimal performance level over long time intervals. They will also maintain robustness and trustworthiness attributes even with growth and evolution in functionality and performance. The program will explore a self-regenerative operating system that will automatically recover after failure of or attack on its configuration files, underlying devices or applications, and provide core survivability functionality, programming interfaces and system services that support rapid prototyping, construction, and deployment of survivable applications.

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(U) Program Plans:

- Demonstrated scalable data redundancy for network-centric military applications and infrastructure services.
- Developed techniques for natural robustness via biological metaphors to counter vulnerabilities of software monocultures in military information systems.
- Develop technologies to diagnose and assess damage, repair and recover from damage caused by accidental faults, software aging or malicious activities, and enable systems to heal automatically.
- Develop strategies to preempt insider attacks, including inferring military system operator goals, enabling anomaly detection, combining and correlating information from system layers, and using direct user challenges.
- Develop a cognitive framework that ties the SRS technologies together and allows feedback and cognitive control of the overall system's survivability posture.
- Develop an exemplar self-regenerative system tailored to protect a representative military application in order to demonstrate the value to the warfighter.
- Develop operating system structures, building block mechanisms and application programming interfaces (APIs) that are individually survivable.

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

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY	R-1 ITEM NOMENCLATURE
RDT&E, Defense-wide BA2 Applied Research	Cognitive Computing Systems PE 0602304E, Project COG-02

COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Cognitive Computing COG-02	85.187	88.931	121.263	126.194	130.630	139.992	140.741

(U) Mission Description:

(U) In the real-time environment of military operations, cognitive networks and systems that can learn, reason, draw on their experience, automatically adapt to maintain critical functionality, effectively assist their military user and improve their responses over time will be crucial to operational success. These capabilities will make the difference between mission success and mission degradation or failure, even in the event of cyber-attack or component attrition resulting from kinetic warfare or accidental faults and errors. Systems that learn and reason will reduce the requirement for skilled system administrators and dramatically reduce the overall cost of system maintenance. As the military moves towards a dynamic expeditionary force, it is critical for systems to become more self-sufficient.

(U) The Cognitive Computing project will develop core technologies that enable computing systems to learn, reason and apply knowledge gained through experience, and to respond intelligently to new and unforeseen events. These technologies will lead to systems with increased self-reliance, intelligent negotiation capability, cooperative behavior, the capacity to reconfigure themselves, and survivability with reduced programmer intervention. In cognitive architectures, there are three primary types of processes: reactive, deliberative and reflective. Reactive processes respond quickly and directly to known stimuli; deliberative processes embody what is usually known as “thinking;” and reflective (higher-order) processes allow a system to “step back” and evaluate the environment and its own capabilities to decide the next appropriate course of action. Each of these processes will be improved through learning. Individual technical capabilities developed in this project include novel representations for knowledge, skill learning, algorithms for automated reasoning (deductive, abductive, planning, strategic inference, and hybrid approaches), pattern detection capabilities, and language learning. Overall, the project will extend fundamental computing capabilities to deal with real-world information complexity and uncertainty.

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(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Integrated Cognitive Systems	47.814	52.721	62.982

(U) The Integrated Cognitive Systems technology thrust will develop advanced technology to enable a new class of integrated, highly functional cognitive systems capable of greatly assisting military commanders and decision makers. This thrust will build upon prior DARPA programs that developed improved human-computer interaction capabilities and highly-responsive computing systems. Integrated cognitive systems will seamlessly fuse perceptual inputs and tie newly perceived data to prior knowledge and experience. They will be able to plan ahead and will understand the world well enough to plausibly anticipate future events. Most importantly, these systems will have embedded learning capabilities that will allow them to retain prior learned knowledge, apply this knowledge to new scenarios, and ultimately provide faster and more effective responses. Overall, the ability to learn will enable the performance of a cognitive system to improve over time. The Integrated Cognitive Systems technologies will be developed and demonstrated in the Personalized Assistant that Learns (PAL) program.

(U) The Personalized Assistant that Learns (PAL) program will develop integrated cognitive systems that act as personalized, executive-style assistants to military commanders and decision makers. This program will demonstrate cognitive systems that use basic knowledge and past experience to help them understand and seek input. Initially the program will strive to create assistant programs that display basic interaction competencies with people and other assistant programs in an operational environment. Some of these basic competencies include sending and receiving information in a natural manner, relating information and activities in various media, interacting with the assistant's user and inferring preferences, executing procedures correctly; and accepting coaching and guidance expressed in natural language. In a unified multitasking, mixed-initiative architecture, these integrated cognitive systems will push the limits of technology for formal reasoning and learning. Methods for processing raw data will be learned in a way that optimizes performance of the entire system and enables the same purposeful perception that makes natural systems successful in dealing with huge amounts of input data and a constantly changing world. One of PAL's goals is the development of advisable systems technology that yields systems that warfighters and other end-users can control in a natural and flexible manner, e.g., by exchanging advice and instructions, rather than via menus or programming. The term "advice" refers to a series of instructions that span a spectrum ranging from high-level policy and goals, to intermediate preferences and constraints on system behavior, to specific direction and

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contingency actions. The end user will be able to engage in a natural dialogue with the system, and the advice will be translated into an executable form.

(U) Program Plans:

– Personalized Assistant that Learns
  - -- Developed an understanding of user preferences and basic operational procedures.
  - -- Developed test problems and defined metrics to evaluate progress in integrated cognitive systems technology R&D. Conducted formal experiments annually.
  - -- Developed compelling scenarios to drive advisable technology research through a series of increasingly difficult challenge problems.
  - -- Developed, evaluated and improved an integrated research prototype. Effort continues on an extended prototype.
  - -- Develop, demonstrate and refine core machine learning, knowledge base and flexible planning technologies to enable development of a cognitive planning agent.
  - -- Develop, demonstrate and evaluate core physical awareness, cyber-awareness, multimodal dialogue, machine learning, and representation and reasoning technologies to support cognitive assistant executive functions.
  - -- Develop and demonstrate the ability to learn quickly from a few examples, learning by accepting guidance from its user, and asking for guidance when needed.
  - -- Develop and evaluate techniques for learning in one domain and applying the learned knowledge in a new unanticipated domain.
  - -- Develop the ability for an integrated cognitive system to examine its own behavior and learn from that experience.
  - -- Develop a dialogue system with general and domain-specific semantics for eliciting natural language advice from the warfighter and other end users. This dialogue system will translate user guidance into the precise languages necessary for both implementation and verification of purpose and intent.

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	FY 2005	FY 2006	FY 2007
Foundational Learning Technology	22.857	19.819	33.057

(U) The Foundational Learning Technology thrust seeks to develop advanced machine learning techniques that enable cognitive systems to continuously learn, adapt and respond to new situations by drawing inferences from past experience. The application of this technology will result in military systems that are more robust, self-sufficient, and require minimal or no platform-specific customization. Current projects will develop hybrid learning techniques to create cognitive systems capable of learning military strategy, leveraging large amounts of prior knowledge, incorporating external guidance and applying prior knowledge in real-time to the naturally changing environment, all without programmer intervention. The Foundational Learning Technology thrust includes three programs: Real-World Learning, Integrated Learning, and Bio-Inspired Cognition.

- The Real-World Learning program will explore the integration and application of advanced machine learning techniques to enable cognitive computing systems that learn from experience and adapt to changing situations. The program will emphasize Transfer Learning providing the ability to transfer knowledge and skills learned for specific situations to novel, unanticipated situations and perform appropriately and effectively the first time a novel situation is encountered. This is essential because currently, most military operations occur in ever changing environment and U.S. forces and systems must be able to act appropriately and effectively the first time each novel situation is encountered. The program will drive the design and implementation of new hybrid learning technologies, such as large-scale transfer learning, multi-purpose extensible knowledge learning, learning with minimal direction, learning adaptable and efficient network structures, bootstrapped strategy learning, learning from text, learning intent of information, and learning generalized task models. The program will stress technologies that combine statistical learning techniques with knowledge-based techniques that take into account background knowledge and *a priori* experience. The resulting technologies will a) learn and represent vast amounts of knowledge in forms that can be applied to unknown situations and domains; b) generalize learned knowledge and apply it to dynamic and unpredictable situations; and c) reason about a situation or environment.

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- The Integrated Learning program will create a new computer learning paradigm in which systems learn complex workflows from warfighters while the warfighters perform their regular duties. Current machine learning technologies cannot learn these complex workflows. The program is focused on military planning tasks such as AOC (air operations center) planning and military medical logistics. With this learning technology, it will be possible to create many different types of military decision support systems that learn by watching experts rather than relying on hand-encoded knowledge (which is expensive and error prone to produce). The new learning paradigm differs from conventional machine learning in that it does not rely on large amounts of carefully crafted training data. Rather, in the new paradigm the learner works to "figure things out" by combining many different types of learning, reasoning, and knowledge. For instance to learn AOC tasks, the computer learner combines: what it observed the warfighters doing with the knowledge it has about aircraft, and the reasoning about airspace deconfliction to create a generalized model that can then be used to perform the entire AOC task or provide intelligent instruction to other warfighters performing the same task.

- The Bio-Inspired Cognition program will draw on continuing advances in neurophysiology and cognitive psychology to guide and augment traditional artificial intelligence (AI) approaches to learning, reasoning, memory, knowledge acquisition and organization, and executive functions. The work will focus on novel designs inspired by the function, representation and structure of the brain. This approach will expand traditional AI technologies from complex symbolic processing to new capabilities in memory, categorization, pattern recognition and fusion of perceptual/sensory information. Computational intelligence is in its infancy, whereas the human brain is the product of millions of years of evolutionary development. Thus, designing software inspired by the brain's processing schemes can offer leap-ahead advances in cognitive systems. These systems will seek to emulate human performance in exploiting past experience in novel situations, learning in multiple ways, fusing multiple perceptual inputs in real-time, extracting concepts from specific experiences, forming hierarchies of associated memories and concepts, and directing attention through a complex executive process. This thrust will take a fresh look at the design and implementation of bio-inspired cognitive architectures modeled after human cognition that combine principles from neuroscience and cognitive psychology with traditional artificial intelligence-based symbol processing and knowledge representation. Success will, in part, be measured by the ability of the systems developed to deal effectively with novel situations and respond appropriately in reasonable timeframes. This thrust has the potential to revolutionize a broad range of military applications through breakthrough performance of intelligent machines.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Cognitive Computing Systems PE 0602304E, Project COG-02

(U) Program Plans:
- Real-World Learning.
  - Selected several critical problems and scenarios to challenge machine learning technology in ways that will determine the essential value of individual techniques.
  - Establish a testbed of complex multi-agent environments for the generation of specific and novel situations that will be used to evaluate learning techniques and components.
  - Design and develop hybrid learning systems that allow cognitive systems to generalize based on information gathered and learned to operate successfully in similar, but not identical situations; adapt to a wide variety of naturally-occurring situations; and perform better over time.
  - Demonstrate the ability of a cognitive agent to learn large amounts of knowledge for performance in a specified domain on an unknown task within the same domain.
  - Demonstrate the ability of a cognitive agent to combine and restructure knowledge from multiple domains to solve novel problems. This includes the ability to generalize knowledge from a particular domain, recognize its applicability and apply it to a problem in a new domain. It also includes the ability to apply knowledge effectively, apply skills acquired for one purpose to other purposes, and demonstrate the ability to propose novel problem solution methods when specified resources are unavailable.
  - Demonstrate the ability of learning techniques to improve representation and reasoning performance in complex multi-agent environments.
  - Develop the ability of a cognitive agent to solve a problem with incomplete and partially inaccurate directions.
  - Develop the ability of a cognitive agent to achieve a goal that is only implicit in a specified task set of directions.
  - Develop software tools that learn to adapt and optimally configure organizational structures, such as military commands, for robust complex decision making (e.g., logistics) and information sharing.
  - Develop software that integrates learning from examples, heuristic reasoning and textual analysis to recognize intent (i.e., cooperative or adversarial) behind human communications, and other information.
  - Develop technologies that allow systems to rapidly learn complex tasks and concepts by automatically understanding the components of complex tasks, and combining information, in a cumulative fashion, from multiple types of knowledge resources, such as manuals, texts, examples, expert behavior traces, and human advice**.**
  - Develop the ability to learn information directly from large volumes of text using existing knowledge to guide the learning.

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– Integrated Learning.
  - -- Formulate learning as integrated problem solving. Develop techniques for representing and reasoning about explicit learning goals, formulating plans to achieve these goals, creating hypothesis where appropriate, and resolving sources of uncertainty.
  - -- Flexibly combine different types of knowledge and reasoning. Enable learners to assemble information from many different sources including general-purpose world knowledge, more specific domain knowledge, reasoning, and simulation.
  - -- Develop a new set of learning algorithms that focus on learning structures or models rather than refining parameter values.
  - -- Develop algorithms that reason about when learning systems should ask humans for explicit input and learn processes efficiently from humans as they perform work tasks.

– Bio-Inspired Cognition.
  - -- Begin using a new generalized theory of learning and memory as well as modular biomorphic designs to implement and integrate simulation modules into a series of biomorphic learning systems.
  - -- Investigate the role of parallel architectures, algorithms, and general principles inspired by neuroscience in hybrid learning and adaptive systems.
  - -- Develop a battery of tests for evaluating cognitive architectures: a “cognitive decathlon” for assessing specific skills associated with cognition (e.g., visual perception, memory).
  - -- Using this battery of tests, compare the performance of biomorphic learning technologies against those of traditional artificial intelligence.

	FY 2005	FY 2006	FY 2007
Learning Locomotion and Navigation	12.038	11.851	18.811

(U) The Learning Locomotion and Navigation thrust will develop learning and reasoning technologies that specifically address concerns in robotic systems. The resulting robotic systems will automatically learn to interpret sensor data and apply this knowledge to the control of their actuators, which will improve locomotive and navigational autonomy in complex environments. Approaches in reinforcement learning and technologies for learning from example will be explored. These technologies will open new horizons for unmanned military operations,

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surveillance and reconnaissance and will dramatically advance the capabilities of autonomous vehicles. Tasks requiring higher-level computation, such as perception-based navigation, will also benefit.

(U) Program Plans:

– Learning Locomotion and Navigation.
  - -- Explore the integration of various learning technologies to enable rapid adaptation by robots to new physical environments and improve autonomous vehicle speed over rough terrain.
  - -- Develop learning methods that allow their learned navigation algorithms to surpass the performance of a baseline system.
  - -- Transfer the best performing navigation methods learned on a small-scale vehicle to the large robotic vehicle, Spinner, to increase speeds in complex environments.
  - -- Explore “learning from example” and “reinforcement learning” applications to develop technology for autonomous vehicle systems to learn from example and from gathered experience without relying on a programmer to anticipate all eventualities.
  - -- Create learning locomotion toolkits that will control a diverse set of high degree-of-freedom vehicles on rough terrain.

	FY 2005	FY 2006	FY 2007
Knowledge-Based Technology	2.478	4.540	6.413

(U) The Knowledge-Based Technology thrust will develop enabling technologies, methodologies, ontologies and detailed knowledge bases to achieve the next generation of intelligent, knowledge-intensive systems. This work will focus on developing technology that spans the spectrum from large, strategic knowledge banks to small, individual knowledge-based systems. The Knowledge-Based Technology thrust comprises Knowledge-Based Systems and Bootstrapping Cognitive Systems with Implicit Semantic Knowledge.

- The Knowledge-Based Systems program will develop technologies to acquire, codify, link, integrate, and use complex and cross-disciplinary knowledge at varying scales. At a strategic level, this capability will provide DoD decision makers with rapid, as-needed access to relevant background knowledge from a broad spectrum of sources. The knowledge will be expressed in formal knowledge representation languages that allow computers to reason with the knowledge, consider its implications, imagine possible future scenarios and query the warfighter for clarification. The significant challenges are centered on the fact that critical knowledge involves temporal

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information, complex belief structures and uncertainty. Current representation technology is inadequate to capture such information. This program will develop technology needed to enable the creation of individual knowledge-based systems that would incorporate into the reasoning process (in a computer-understandable form) knowledge of the warfighter's responsibilities, approach, tasks and activities. Another goal of this program is to support the warfighter's ability to understand the "big picture" for mission planning, monitoring and re-planning. By formalizing situation-model representations, automated support will be provided to commanders and analysts for prediction of unforeseen events and determination of relevance of isolated or partial events to the evolving situation. To achieve these objectives, this program will develop analogical and case-based reasoning, languages and situation markup languages technologies, and formalized situation representations. An additional goal is the development of technologies for rich, high-fidelity simulation models of human learning, reasoning and behavior. The program will also explore new ways for knowledge to be transferred efficiently to a knowledge base by reading tutorial text intended to convey new concepts to a cognitive system.

- The Bootstrapping Cognitive Systems with Implicit Semantic Knowledge program will explore a new technique for creating cognitive systems that learn to perform actions in an intelligent fashion without detailed reasoning or reliance on detailed models of action. Instead, the technique uses large amounts of coarse grained information and usage statistics gathered by watching many warfighters at work. This body of knowledge enables the algorithms to "do the right thing" without detailed computation – replacing detailed knowledge-based inference or planning with statistical usage information. This new technique will lower the cost of creating cognitive systems that perform assistive tasks for our warfighters.

(U) Program Plans:

– Knowledge-Based Systems
  - -- Developed initial techniques for representing and using common sense knowledge.
  - -- Explored novel methods for acquiring new knowledge that is less onerous than traditional methods requiring hand-coding by experts including direct input through processing natural language text.
  - -- Develop and evaluate methods, protocols, and tools for using interoperable knowledge modules resident on distributed knowledge servers.
  - -- Develop integrated knowledge representation and learning technology that enables effective representation of essential forms of knowledge.

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-- Document a substantial library of formal declarative interoperable multi-use ontologies initially across single, then multiple domains.
-- Demonstrate and evaluate prototypes of strategic and individual knowledge-based systems.
-- Develop representations of events and methods for separating and tracking their association to merge multiple scenarios, assimilate one event within the context of the other, and identify where events deviate from the norm.

– Bootstrapping Cognitive Systems with Implicit Semantic Knowledge
-- Develop algorithms based on implicit semantic knowledge that enable cognitive systems to examine a current goal, and then decide how to achieve that goal based on what the warfighter has done in the past.
-- Evaluate and test the implicit semantic knowledge algorithms on a variety of different domains or application areas to assess the utility of the approach and its effectiveness for different applications.
-- Create distributed agent scribes that learn operations from warfighters and stores these operations along with the implicit semantic knowledge in a repository for future automation.

(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 Cognitive Computing Systems PE 0602304E, Project COG-03			
COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Collective Cognitive Systems and Interfaces COG-03	40.846	47.821	61.187	61.226	61.751	63.751	61.751

(U) Mission Description:

(U) The Collective Cognitive Systems and Interfaces project will dramatically improve warfighter and commander effectiveness and productivity by developing revolutionary methods that increase the individual warfighter's/commander's information processing capabilities, enhance situational awareness in urban and battlefield operations, and enable team collaboration through ensured network communications.

(U) A unique aspect of natural perceptual systems is their ability to filter and integrate vast amounts of raw sensor data, such as visual flow and rich auditory input; rapidly segment the resultant data into meaningful elements; and integrate them into a coherent picture. The human perceptual system is able to create perceptual units that parcel the world into objects and discrete entities that are then recognized, remembered and used in problem solving. Looking closely at these innate perception abilities will yield insights into how to build totally novel computational systems that identify important, low-frequency events in a noisy environment. This kind of approach should lead to dramatic improvements in the ability of a computer to process and analyze huge amounts of data to form a high-level understanding within its environment. Robust interaction among cognitive systems, legacy systems and warfighters will require incorporation of advanced models and control of the network infrastructure to ensure adequate provisioning of quality-of-service under dynamic loads. Together, these technologies will allow the warfighter to focus on high-level mission objectives rather than low-level maintenance of supporting systems. At the same time the technology will ensure that the warfighter maintains essential understanding of how (and how well) the system is implementing and responding to high-level direction.

(U) This project will focus on methods for users to interact with and direct cognitive systems (including the physical sensors and effectors); technologies to reduce the personnel and labor required for set up and maintenance of tactical and strategic networks; and techniques for retrieving and interpreting relevant collected information. High-level languages will be developed for rapid and precise specification of complex behavior in response to mission demands. Since it is equally important for the warfighter or commander to understand the system as it is for the system to understand the user's goals and needs, this project will develop technologies that give systems the ability to explain, perceive and reason about their behavior and actions. While development of stand-alone cognitive systems represents a huge leap forward, real, complex military missions require teams of these systems to work collaboratively. The project will also develop those technologies necessary to enable such systems to collaborate effectively and take advantage of the power of collective cognitive agents.

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(U) The suite of programs under this project will significantly advance the military's ability to address and deal with complex situations in operational environments.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Improved Warfighter Information Processing	8.387	8.225	9.000

(U) The Improved Warfighter Information Processing (IWIP) technology thrust is developing technologies to enhance the warfighter's and commander's information management capacities and improve decision-making performance. The main thrust of this program is the Improving Warfighter Information Intake under Stress program. The Improving Warfighter Information Intake under Stress program will enhance operational effectiveness through a set of cognitive techniques that specifically improve 1) the amount of information that warfighters can handle, thereby reducing manpower requirements (e.g., one person doing the job of three); 2) attention management during stressful operations; and 3) information retention (memory). The program will develop the means, devices and infrastructure necessary to assess the warfighter's or commander's cognitive status in real time, and use adaptive strategies specific to his/her status to improve information processing and decision-making. The program will develop the technologies to integrate new digital devices that support memory, attention, and context recovery; and will culminate in the development of closed-loop systems that enable computer systems to adapt to the warfighter's or decision-maker's cognitive status. The research is also pursuing perceptual processing-based displays that are sensitive to information processing mechanisms inherent in the human perceptual system to invent, modify and redesign devices that more effectively deliver content to the operator. Such work will include designing and building adaptive multimodal interfaces that improve the battlefield and command center communications, and exploiting all of the digital information currently available in a static command environment. DARPA has established MOAs with the U.S. Army Research, Development and Engineering Command - Natick Soldier Center; Naval Air Systems Command; Air Force Research Laboratory Human Effectiveness Directorate; Office of Naval Research Expeditionary Warfare Operations Technology Division; and Deputy Chief of Naval Operations, Warfare Requirements and Programs for transition of this program.

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(U) Program Plans:

- Developed and integrated sensor technologies into an initial suite of operationally valid warfighter status "gauges."
- Assessed techniques for classifying warfighter status and operational context for automation engagement under stress.
- Quantified and characterized the information processing mechanisms inherent in the human perceptual system in order to improve warfighter decision-making capabilities, and design novel interactions within the command and control environment.
- Refine closed-loop computational interfaces to mitigate specific information-processing bottlenecks to improve performance and information flow in specific operational domains.
- Refine intelligent interruption strategies, adaptive attention management methods, cued memory retrieval strategies and modality switching techniques to effectively increase information processing capacities in complex environments under stressful, operationally realistic conditions.
- Ruggedize the system to enable the assessment and enhancement of warfighter performance for an order-of-magnitude improvement in operator efficiency.
- Demonstrate ruggedized, operational prototypes for transition to service components.
- Design and demonstrate visual displays and rich audio interfaces to provide the foundation for adaptive displays that adjust to the operator, task and/or display device.
- Design and develop new mobile-adaptive multimodal processing techniques and interface concepts tailored to the user, task, and environment; test performance and usability advantages within multimodal systems and identify protocols for maximized information presentation.

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	FY 2005	FY 2006	FY 2007
Collaborative Cognition	20.546	21.304	24.001

(U) The Collaborative Cognition thrust is aimed at developing technologies that enable individual cognitive agents to work together as a team to provide cooperative support to warfighters in complex military situations. Such situations typically require multiple coordinated tasks that involve information sharing and cooperative efforts. The Collaborative Cognition thrust will foster the design and implementation of collaborative software agents that operate in dynamic environments and include both software agents and people. Applications include collaborative surveillance and reconnaissance systems, logistics re-planning and decision support for unanticipated operational changes, situational analysis, prediction tools, and other aids to warfighter/commander decision making. The technology will also allow software agents to cope with limited and/or noisy sensor information, limited communication capabilities, changing and unforeseen environments, other agents, and limited *a priori* knowledge of each other's capabilities. The Collaborative Cognition technology thrust consists of two programs: Coordination Decision-Support Assistants (COORDINATORs), and Advanced Soldier Sensor Information System and Technology (ASSIST).

- The Coordination Decision-Support Assistants (COORDINATORs) program will develop cognitive software coordination managers that provide support to fielded tactical teams. The coordination managers will help fielded units adapt their mission plans in response to inevitable, unanticipated changes in the mission by tracking personnel, resources, situational changes, and proposing and evaluating options (adjustments to task timings, changes to task assignments and selection from pre-planned contingencies). This will enable fielded units to respond faster and more accurately to the dynamically changing battlefield situation, requiring far fewer personnel in the re-planning process. COORDINATORs is a distributed technology. A single COORDINATOR will be partnered with each tactical unit or team, and will be able to collaborate and coordinate with other tactical units to optimize needed mission changes.

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- A key lesson learned from Operation Iraqi Freedom (OIF) is the importance of accurate observational reporting by ground soldiers. The Advanced Soldier Sensor Information System and Technology (ASSIST) program will develop an integrated information system that exploits soldier-worn sensors to augment the soldier's ability to capture, report, and share information in the field. Communication of timely and accurate information is vital for enhanced situational understanding and overall operational effectiveness in urban combat and post-conflict stability operations. While a range of standardized reporting mechanisms are in use today, the confusion of the battlefield/urban operations combined with physical and psychological stresses on the warfighters can make the task of reporting very difficult. Furthermore, existing verbal and text-format reports limit the soldier's ability to capture and convey the full picture, particularly annotated visual information. The ASSIST program will develop an integrated system using advanced technologies for processing, digitizing and analyzing information captured and collected by soldier-worn sensors. It will draw heavily on the experiences and lessons learned from previous OIF missions and other surveillance and reconnaissance missions. A baseline system will demonstrate the capture of video/still images together with voice annotations and location-stamping. The advanced system will demonstrate automatic identification and extraction of key objects, events, activities and scenes from soldier-collected data. The system will create knowledge-based representations that will serve as an input to an array of warfighter products including augmented maps, situational analysis tools, and query and answer capabilities.

(U) Program Plans:

– Coordination Decision-Support Assistants
  - -- Develop distributed coordination technology that reasons about making changes to task timings, assignments, and selection from preplanned contingencies.
  - -- Develop a coordination autonomy technology that learns which response options are most highly valued so that the COORDINATORs generate an appropriate option when the warfighters are occupied or cannot be interrupted.
  - -- Develop a meta-cognition technology that reasons about resource allocation (i.e., where a given COORDINATOR should spend its processing time), so the entire system can engage in difficult processing tasks but still respond in real time.
  - -- Create algorithms that reason about military decision-making policies and procedures so COORDINATORs follow correct information exchange protocols and ensure that decisions and recommendations stay within the scope of authorization.

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- Advanced Soldier Sensor Information System and Technology (ASSIST)
  - Demonstrate the baseline capture and retrieval system prototype and evaluate the effectiveness of the integrated system in MOUT (Military Operations on Urban Terrain) field exercises.
  - Develop algorithms to identify objects, events, and activities in captured data and assign correct labels.
  - Exploit multimodal sensor streams and contextual information.
  - Create a taxonomy of objects and events, collect test data, and develop procedures and metrics for advanced technology evaluation.
  - Develop a laptop-based user search and visualization interface for accessing logged information captured by multiple soldiers.
  - Demonstrate temporal event representation and outdoor spatial representation.
  - Develop key technological components that enable in-field data sharing and retrieval on a handheld platform.
  - Demonstrate the system's ability to improve its event and object classification performance through learning; demonstrate an accelerated capability for recognizing new classes of events, objects and activities.
  - Integrate advanced multimodal sensor event and object extraction techniques into advanced systems and evaluate the enhanced capabilities.

	FY 2005	FY 2006	FY 2007
Self-Sufficient Collective Systems	1.913	2.690	5.172

(U) The Self-Sufficient Collective Systems technology thrust will allow heterogeneous teams (e.g., people, software agents, robots) and/or organizations (e.g., coalition forces) to rapidly form, easily manage and maintain virtual alliances concerned with specific problems, tasks or requirements. The technology will improve information sharing and situational awareness by robustly and dynamically networking teams of agents and warfighters. Self-Sufficient Collective Systems concepts will enable warfighters to take full advantage of all available information and bring to bear all available assets in a rapid and flexible manner. This thrust includes the Cognitive Collectives for Autonomic Situation Awareness initiative, which will create software technologies that enable future warfighters to form collective units and share information automatically for broad tactical battlespace awareness. The selection, generation, sharing and display of information will be handled by cognitive software systems coupled with each warfighter, and the network of individual systems will form a collective. Each system will monitor the sensors attached to its

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associated soldier, collect situational information and reason about the soldiers' operational environment. Selected information will then be communicated to nearby units via their systems. As each unit continues to share information with nearby units, the information will be propagated throughout the collective to enhance the capability of the individual soldier.

(U) Program Plans:

- Create multi-layer cognitive software systems where lower layers respond in a reactive fashion and higher layers perform deliberation/reasoning, learning and diagnosis.
- Create learning algorithms that learn over time to distill the reasoning that happens at the higher levels into lower level autonomic responses.
- Design new approaches for reasoning about information longevity, information fusion, and handling conflicting information from different sources to enable the warfighter's systems to concurrently operate in multiple information collectives.
- Develop algorithms that reason about the edge-of-stability for learned/autonomic responses, i.e., understand when autonomic responses should be changed or updated because the situation has changed or these responses no longer apply.
- Develop new techniques for designing or organizing distributed computation to achieve a goal-directed behavior.
- Create a problem-solving infrastructure with the ability to dynamically organize and decompose problems.
- Plan for problem solving, monitor progress, and adapt to changing capabilities.
- Develop robust teamwork models with the ability to dynamically reconfigure teams of robots and humans to execute missions in rapidly changing adversarial environments.
- Transform software engineering by exploiting *meta-information* comprising ontology of intended environment, design constraints, and limitations.

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	FY 2005	FY 2006	FY 2007
Cognitive Networking	10.000	15.602	23.014

(U) The Cognitive Networking research thrust will develop technologies that provide information systems and communication networks with the ability to maintain their own functionality, reliability and survivability. These technologies will allow the military to focus its critical manpower resources on the mission rather than on the maintenance of its information systems and network infrastructure. Research in this area will create a radical new design for distributed computers, device networks, and the software to manage these systems. It will also attempt to create a "cognitive enhanced radio" capability, which uses cognitive information processing to optimize communications based on current conditions, past experience and high-level user guidance. This research thrust will also explore adaptive command, control, communications and computers (C4) network planning and design capability that dramatically reduces life-threatening communication failures in complex communication networks. The Cognitive Networking thrust comprises three programs: Situation-Aware Protocols in Edge Network Technologies, Adaptive Cognition-Enhanced Radio Teams and Brood of Spectrum Supremacy.

- The Situation-Aware Protocols in Edge Network Technologies (SAPIENT) program will develop a new generation of cognitive protocol architectures to replace conventional protocols that fare poorly in extreme network conditions and do not provide adequate service for key applications. Technology developed in the SAPIENT program will have military utility wherever tactical communications are deployed. SAPIENT architectures will represent awareness with a knowledge base that is updated based on specification and observation. This technology enables the automatic adaptation of protocols to the operational environment. SAPIENT will exploit attributes of human cognition, such as learning and self-improvement and apply them to the automated construction of network protocols. Key research challenges for the SAPIENT program are the use of these cognitive attributes to dramatically reduce the effect of network impairments on applications while demonstrating a positive trend in this capability as new situations are encountered and learned. Desired capabilities include interoperable knowledge representations and rapid incorporation of new knowledge about applications, network conditions and building blocks from which new protocols can be constructed.

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- The Adaptive Cognition-Enhanced Radio Teams (ACERT) program will construct a distributed radio team that is able to use capabilities inherent in aggregating nodes, while leveraging advantages that are unique to a distributed system. Thus, ACERT platforms will focus on resource management to facilitate basic radio capabilities and accommodate the allocation of resources necessary for the individual radios to be combined into a team. In addition, since membership in a radio team strongly affects the capabilities of the aggregate, ACERT radios will provide robust access control for the radio team's resources. Therefore, resource management of ACERT platforms will be carried out at machine speeds to overcome intermittent connectivity, dynamic team membership, and the requirements of the individual team member radios. This capability will provide more reliable communications for small unit operations in urban environments.

- The Brood of Spectrum Supremacy (BOSS) program will provide actionable situational awareness to the warfighter in complex RF (Radio Frequency) environments. BOSS adds collaborative processing capabilities to tactical software-defined radios to achieve specific military goals, such as understanding the adversary's organization. BOSS exploits cooperative use of computational, communication and sensory capabilities in a software radio, in aggregate, to generate breakthrough capabilities in the warfighter knowledge of their surroundings, with a particular focus on RF-rich urban operations. The BOSS program will initially focus on modeling and simulation, resulting in hardware-independent executable specifications of waveforms in an interoperable format. Once the modeling and simulation is verified, the BOSS program will develop a prototype demonstration capability for a performer-selected RF platform, using and refining the hardware-independent executable specifications of the waveforms. Ultimately this program will develop Software Communications Architecture (SCA)-compliant waveforms suitable for implementation on a tactical software radio system.

(U) Program Plans:

– Situation-Aware Protocols in Edge Network Technologies (SAPIENT)
  - -- Developed a suite of fundamental protocol components appropriate for these situations.
  - -- Developed and implemented a selection and composition methodology to exploit situation awareness to construct a functioning network protocol adapted to the situation.
  - -- Create and refine knowledge representations appropriate for describing situations encountered in tactical military networks (e.g., weak signals, propagation obstructions, message priorities and security requirements) and for enabling machine response to these situations including automated learning of effective responses.
  - -- Integrate and enhance prototypes and evaluate their performance.

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-- Perform analysis of requirements for C4 capabilities including contingent event specification and network requirements representation.
-- Identify strategies for automating the configuration reasoning tasks for C4 networks of realistic scale.

– Adaptive Cognition-Enhanced Radio Teams (ACERT)
-- Create models, algorithms, and prototypes for distributed control of radio resources and shared situational awareness.
-- Design and implement team access controls including new models for decentralized trust and new algorithms that take advantage of locality and density.
-- Manage collaborative channel characteristics including leveraging of the broadcast channel for shared awareness.
-- Develop cross-layer optimizations and possibilities for cognitive Media Access Control (MAC) layers that improve team performance over time.

– Brood of Spectrum Supremacy (BOSS)
-- Develop theoretical analyses of the software-defined radio trade space to assess the distributed aggregation of capabilities over different numbers of moving elements, elements with varying capabilities (e.g., RF and processing), and with different distances and locations.
-- Refine capabilities of Software Communications Architecture (SCA)-compliant platforms, while working within the software-defined radio trade space.
-- Validate algorithms and implementations for network understanding tasks that could, for example, locate and identify likely commanders and command posts.

(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 Biological Warfare Defense PE 0602383E			
COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	155.360	148.108	112.242	110.695	110.618	110.914	110.414
Biological Warfare Defense Program BW-01	155.360	148.108	112.242	110.695	110.618	110.914	110.414

(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, prevention, treatment and remediation. This project funds programs supporting revolutionary new approaches to biological warfare (BW) defense and is synergistic with efforts of other government organizations.

(U) Efforts to counter the BW threat include developing barriers to block entry of pathogens into the human body, countermeasures to stop pathophysiologic consequences of biological or chemical attack, host immune response enhancers, medical diagnostics for the most virulent pathogens and their molecular mechanisms, biological and chemically-specific sensors, advanced decontamination and neutralization techniques, and integrated defensive systems, including detection of chemical and biological agents in sealed containers at entry points of facilities. This program also includes a unique set of BW sensors that will greatly improve sensitivity while decreasing response time. Program development strategies include collaborations with pharmaceutical, biotechnology, government, and academic centers of excellence.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Unconventional Therapeutics	38.380	37.202	35.000

(U) This thrust is developing unique and unconventional approaches to ensure that soldiers are protected against a wide variety of naturally occurring, indigenous or engineered threats. Past successes in this effort have come from developing therapeutics that are designed to work against broad classes of pathogens. This has led to several significant transitions, a separate thrust in Anthrax countermeasures, and most recently

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a new program at DTRA that directly capitalizes on previous DARPA investments. Work in this area has also uncovered new approaches to therapeutics that, rather than attacking specific pathogens, enhance human innate immune mechanisms against broad classes of pathogens. Not only will these approaches be more effective against known pathogens, they also promise to offer substantial protection against unknown pathogens including engineered pathogens and emerging pathogens from third-world environments. An emphasis is on the discovery and development of technologies that will allow a rapid response (within weeks) to unanticipated threats, whether they are naturally encountered emerging diseases or agents from intentional attack. In this regard, this thrust addresses the development of in vitro systems that directly mimic the human immune response and can be used for rapid development and screening of human vaccines. An additional focus is the development of entirely new technologies that will allow the rapid, cost-effective manufacture of complex therapeutic proteins such as monoclonal antibodies and vaccine antigens.

(U) Program Plans:

- Demonstrated and transitioned to DoD a phage-based therapy and assay for anthrax.
- Demonstrated the ability of CpG to enhance the effectiveness of the Anthrax Vaccine Absorbed (AVA) anthrax vaccine by 8-fold.
- Demonstrated a new antimicrobial target for CIPRO-resistant anthrax that is common to all CIPRO-resistant organisms.
- Demonstrated siRNA as a new platform against highly virulent influenza and other respiratory viruses.
- Demonstrated inhibitors of apoptosis as potential countermeasures to anthrax and other pathogens.
- Developed in vitro fabrication of three-dimensional tissue constructs, bioscaffolds and bioreactors.
- Demonstrated that precursor immune cells can be expanded and differentiated into reactive T cells in the artificial immune system.
- Demonstrated generation of functional immune structures by dendritic cells in the artificial immune system.
- Demonstrated antibody class switching in the artificial immune system.
- Develop and demonstrate an integrated in-vitro immune system that will emulate the human immune response in order to provide a means of evaluating new BW vaccines and therapeutics.
- Demonstrate the ability to predict known vaccine immunogenicity in humans solely by testing in the artificial immune system.
- Develop a scalable, stable, *in vitro* system for the production of the cellular components of human blood to reduce military logistics burden and improve survival during CBRN attack.
- Develop and validate new in vitro systems to predict toxicology of vaccines and immune modifiers.
- Develop a technical framework for the synthesis of millions of doses of a protein therapeutic within 12 weeks.
- Develop new approaches for rapid, high-yield synthesis of therapeutic proteins in bacteria, fungi, and yeast.

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- Develop new methods for purification of therapeutic proteins from high-yield fermenters.
- Develop new approaches for assuring correct folding and mammalian post-translational modification of proteins by bacteria and fungi.

	FY 2005	FY 2006	FY 2007
External Protection	11.000	15.500	16.542

(U) This program is developing and demonstrating a variety of external protection technologies to protect soldiers from the hazards of chemical, biological and radiological attack and other hazards such as large unstable weapons stores. The program includes the autonomous detection and self-cleaning of surfaces contaminated by an attack, and the safe neutralization of hazardous materials.

(U) Program Plans:

- Developed new approaches for self-decontaminating surfaces that will be self-cleaning and be able to deactivate spores.
- Developed and demonstrated new approaches for widespread external decontamination.
- Design, develop and demonstrate systems to detect contaminated surfaces down to the human toxicity levels, and to remove the contamination to below those levels.
- Develop and demonstrate active coatings that can be applied to buildings to provide protection against chem-bio attacks.
- Develop and demonstrate a microbial based demilitarization of such hazardous materials as explosives stockpiles.

	FY 2005	FY 2006	FY 2007
Advanced Diagnostics	6.000	7.854	8.000

(U) In the early stages, many illnesses caused by biological warfare (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 program 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

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identify the pathogen even in the absence of recognizable clinical signs and symptoms (i.e., while the pathogen numbers are still low). Novel approaches including the use of breath and advanced mathematical analysis will be examined.

(U) Program Plans:

- Demonstrated new rapid microfluidic diagnostic technique for separation of pathogens and immune cells.
- Demonstrated the detection of volatiles specific for explosives in the breath of explosive handlers.
- Develop hyperspectral approaches for presymptomatic diagnosis of exposure to pathogens or other medical issues (including naturally occurring disease) that affect soldier health and performance.
- Validate the presence of explosive volatiles in breath in the presence of a number of confounder variables.
- Adapt biosensors for breath-based diagnostics.
- Evaluate and demonstrate multiplexed pathogen detection in microliter samples.
- Develop new mathematical and diagnostic approaches to interpret biosignature data from individuals to determine if there will be a change in physiological status from health to disease and vice versa. Use these data to identify the kind of disease and need for treatment.

	FY 2005	FY 2006	FY 2007
Sensors	46.480	48.000	35.000

(U) The Sensors program goal is to develop a unique set of BW sensors that will greatly improve sensitivity and response time to bacteria, viruses and/or toxins.

(U) The overall goal of DARPA’s Handheld Isothermal Silver Standard Sensor (HISSS) program is to develop a sensor that is capable of detecting the entire biological warfare threat spectrum (bacteria, DNA viruses, RNA viruses and protein toxins) with the same “silver standard” specificity as current laboratory techniques, but in a fast, reliable, handheld unit. Today, this standard is achieved for DNA and RNA threats using polymerase chain reaction, which is slow because of the associated temperature cycling. For proteins, the standard is met using Enzyme Linked Immunosorbent Assay (ELISA), which requires skilled laboratory technicians to complete. The equipment required for these tests is bulky and difficult to use under field conditions. Under HISSS, DARPA will develop fundamentally new ways to exploit previously developed identification

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mechanisms (DNA and RNA primers, protein antibodies) in an integrated, isothermal system that will allow a single, handheld sensor to detect the full range of BW threats.

(U) Program Plans:
- Developed isothermal assays for DNA, RNA and protein toxins and demonstrated a false-alarm rate equivalent to the current laboratory technology.
- Developed a microfluidics testbed for assay optimization and system integration.
- Demonstrated that HISSS isothermal assays have a false alarm rate that is better than the current laboratory technology.
- Develop stabilized reagents for fieldability.
- Design and build a prototype HISSS device.
- Characterize HISSS prototype in laboratory and operational environments.

(U) Triangulation Identification for Genetic Evaluation of Biological Risk (TIGER). Most nucleic acid-based sensors search for an exact sequence match to some unique part of each pathogen. This requires a unique set of primers and probes for every target pathogen; it also means that the sensor can only determine whether that specific (portion of the) target pathogen is present. DARPA is developing a new kind of DNA-based sensor that searches out the universal parts of the genetic code and looks for species-specific variation between these regions. This TIGER sensor will enable a universal sensor for all pathogens and also holds the promise of detecting the presence of never-before-seen (bio-engineered) agents.

(U) Program Plans:
- Develop capability to perform phylogenetic classification of unknown or genetically modified organisms.
- Optimize system to perform automated calibration to quantify number of organisms present in samples and allow multiplexing of primers to reduce costs.
- Transition and deploy fieldable prototype to support operational bio-protection efforts at USAMRIID and NHRC San Diego and forensic analysis at National Bioforensic Analysis Center (NBFAC).

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(U) Spectral Sensing of Bio-Aerosols (SSBA). Active probing of bioaerosols with electromagnetic (EM) energy holds the promise of extremely fast, and potentially long-range, detection and identification of bio agents. Only a small portion of the EM spectrum is exploited in today's trigger sensors (e.g., optically based particle sizers, sometimes enhanced with fluorescence measurements). However, anecdotal evidence suggests that other portions of the spectrum may offer substantial improvement in trigger sensors, as well as potentially agent-specific discrimination capability. Various types of spectra in the visible, infrared, and additional UV wavelengths are being measured in laboratory or early prototype systems. Additional spectral information such as UV fluorescence lifetime and single particle mass spectroscopy is also being evaluated. DARPA is investing in this approach, beginning with cross-spectrum data collection and performance models, followed by prototype sensor development. An aerosol testbed has been developed to provide calibrated exposures of threat agent simulants.

(U) Program Plans:
- Completed bioaerosol testbed and standardized data-collection protocols to allow the new sensor technologies to be challenged with both threat agent simulants and typical interferents such as diesel smoke, pollen and natural fibers.
- Investigated spectral response of chemicals unique to BW agents (e.g., picolinic acid in anthrax spores).
- Collected data, and developed performance model, for concepts that exploit a wide part of the electromagnetic (EM) spectrum (e.g., Raman scattering, terahertz spectroscopy, laser-induced breakdown spectroscopy, coherent Raman anti-Stokes spectroscopy, IR/photoacoustics, etc.).
- For sensors that can characterize and separate single particles, evaluated use of mass spectrometry for particle identification.
- Downselected to most promising concepts; design, build, and test prototype sensor.
- Characterize prototype behavior in operational environments.

(U) Rapid Proteomics to Detect Bioengineered Threats. The goal of this program is to develop and employ rapid proteomic approaches for the detection and identification of bioengineered microorganisms. These organisms potentially can be designed to have the lethal effects of dangerous pathogens by incorporating the genetic sequences that encode toxins into otherwise benign, naturally occurring organisms. The general concept for this type of bioengineering is well known and used extensively industrially to produce such products as human insulin. Clearly such biotechnology could be subverted to produce materials dangerous or deadly to humans while evading conventional detection. A novel approach to detecting such organisms would target the active, functional components required to engineer the organisms. For instance specific types of antibiotic resistance are nearly universal properties of engineered organisms. A method will be developed that uses rapid protein detection

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coupled with bioinformatics to target the proteins associated with these antibiotic resistance genes. Thus this universal pathway to bioengineered organisms would be detected. This approach would close a critical gap in the detection of advanced biological threats to the military.

(U) Program Plans:

- Develop target sets of protein signatures indicative of genetic manipulation.
- Develop and test proteomic tools to detect target protein signatures.
- Integrate proteomic tools into detection systems for genetically manipulated organisms.
- Conduct laboratory and field tests of detection system.
- Transition systems to Joint Program Executive Office - Chem Bio Defense (JPEO-CBD).

(U) Remote Radiation Detection via Intercepted Ultraviolet Scintillation (RRaDIUS). The RRaDIUS program will develop coatings containing crystals that scintillate ultraviolet (UV) photons upon interaction with ionizing radiation. RRaDIUS will also develop deployment and detection systems that will allow for surreptitious coating application and detection of UV photons at a distance. A notional approach includes the firing of a “paintball” that will coat a vertical surface. Resulting UV photons emitted from the coating will be intercepted remotely to determine the radiation level at the coated surface. RRaDIUS will leverage coating technologies developed in the Wide Area Radionuclide Detection (WARD) portion of the Radiation Decontamination (RD) Program. RRaDIUS will also develop new technologies for the collection and amplification of signal from small area (square centimeter range) coatings at a distance.

(U) Program Plans:

- Evaluate RD Program/WARD-developed technologies to identify a UV scintillant that is activated via ionizing radiation and emits UV photons near the solar blind region.
- Incorporate the scintillant into a ballistic-delivered coating or paint; match with existing ballistic paint delivery systems.
- Develop a remote detection, UV camera capable of identifying and quantifying the UV scintillation photons at a distance of at least 100 meters, and sustaining an indirect detection capability of a minimum of 1 microGray (100 microrads) per hour.

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Immune Buildings	21.000	12.500	0.000

(U) DARPA is developing technologies for integrated defensive systems to be employed in military buildings to protect and respond to the emerging threat of aerosolized Chemical, Biological and Radiological (CBR) releases. The approach is to modify and augment the infrastructure of buildings to allow them to sense and defeat an attack by bio or chem agents in real-time and to find and remove hazardous radiation left behind by a "dirty bomb." The program has three goals: to protect the human inhabitants from the effects of the agents; to restore the building to function quickly after the attack; and to preserve forensic evidence for treatment of victims, if necessary, and for attribution. For CB releases, 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 developing component technologies such as optimized filtration systems, advanced neutralization techniques, active building coatings, and remediation techniques appropriate to biological, chemical, and radiological decontamination. In addition, DARPA is investigating the systems-level issues of integrating and optimizing such active systems, including the integration and adaptation of sensors, as well as the simulation of threat events and emergency responses. Several new chemical and biological sensors have been identified for development to address problems that are unique to the building application. Self-assembling nano-structures for building sealants will be investigated to quickly and inexpensively coat building exteriors and completely seal the building, thereby making effective the defensive strategy of sheltering in place. These efforts have used full-scale test facilities to determine the effectiveness of protection components and the optimal architectures for protection. These systems are being transitioned to a full-scale demonstration of a complete building protection system at a military installation and will also leave behind a software tool for the design and optimization of building-protection systems for other military facilities.

(U) Program Plans:

- Developed high-payoff component technologies in the areas of filtration, neutralization, and decontamination; and matured sensors for active CWA/BWA defense applications.
- Continue development of neutralization and building sealant technologies and reduced-false-alarm CW and BW sensors.
- Transitioned rapid-viability testing methods to USAMRIID and Department of Homeland Security (DHS); and decontamination techniques to Joint Program Executive Office–Chem Bio Defense (JPEO-CBD), DHS, and Environmental Protection Agency (EPA).
- Demonstrated performance of component technologies in full-scale prototypes.

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- Optimized active protection system concepts and demonstrated performance in full-scale tests.
- Integrated existing models, and developed new models when required, into a software toolkit that enables performance predictions for protective architectures for diverse building types.
- Selected a site for full-scale demonstration in an operational military building.
- Characterize the demonstration site facility and develop a prototype active protection system optimized for that site.
- Validate toolkit predictions in full-scale test beds and at demonstration site.
- Extend the software toolkit to provide cost analysis of protective system and further validate with performance and cost data from the demonstration site.
- Develop Stimulated Hyper-Accelerated Radionuclide Kinetics (SHARK) technologies to hyper-accelerate description of radioactive contamination within building materials and to rapidly mobilize the contamination of outer building surfaces for more efficient removal.
- Install complete IB protective system in an active military facility at Ft. Leonard Wood, MO.
- Transition IB systems to the US Army Chemical School and US Army Corps of Engineers.

	FY 2005	FY 2006	FY 2007
Chem Bio Defense (CBD) Portal Security	5.000	0.000	0.000

(U) There is an enormous payoff in preventing the release of biological warfare agents (BWAs) and chemical warfare agents (CWAs), rather than trying to minimize the damage they cause once released. For this reason, DARPA has invested in technologies and systems to prevent such materials from entering buildings, either in packages or mail, concealed in normal maintenance materials such as wax or paint or as an item hand-carried by a visitor. A variety of energy sources and sensors have been evaluated for their ability to penetrate package and container materials and obtain signatures for anomaly or hazard detection/identification. Novel destruction methods for BWAs were also evaluated. This program is transitioning to the OSD Chemical/Biological Defense Program, PE 0603384BP, Project TT3.

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(U) Program Plans:

- Evaluated non-intrusive technologies for destruction of biological agents (e.g., ultrasound, variable frequency microwave and new techniques for X-Ray and gamma irradiation) and/or for the detection of chemical agents (e.g., associated particle neutron elemental analysis, tera-hertz spectroscopy, dielectric spectroscopy, and swept frequency acoustic interferometry).
- Selected the most promising approaches, and used laboratory instrumentation to evaluate collateral damage and false alarms.
- Developed performance models, carried out system trades, and developed required prototypes/components.

	FY 2005	FY 2006	FY 2007
Threat Agent Cloud Tactical Intercept Countermeasure (TACTIC)	8.500	12.500	10.000

(U) The TACTIC Program will develop and demonstrate the capability to (1) rapidly detect, discriminate and identify an airborne chemical warfare agent/biological warfare agent (CWA/BWA) battlefield threat at stand-off distances, and (2) use countermeasures to neutralize and/or precipitate the threat before it reaches the targeted troops. This program will investigate identification methodologies including: bead-based assays for biological molecules, fluorescent assays for chemicals, retro-reflector assays for chemical and biological agents; all of which can be interrogated with stand-off optical detectors. To accomplish the removal of the threat, technologies that mimic the seeding of rain clouds will be developed for particulate bio-agents, and technologies that polymerize chemical agent vapor will be investigated. Upon successful demonstration of the identification and removal technologies, a system will be developed to demonstrate the removal of chemical and biological simulant clouds from the battlefield.

(U) Program Plans:

- Investigate technologies for CWA/BWA standoff assays that rapidly (within one minute) identify agents.
- Investigate technologies to remove the agent cloud so as to eliminate the threat to unprotected war-fighters.
- Develop models of identification and removal technologies. Carry out systems trades between competing identification and removal technologies.
- Integrate optimal identification and removal components into a prototype system.
- Test prototype system in scaled aerosol test chambers.

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- Demonstrate system in full-scale field trials.
- Transition to Joint Program Executive Office - Chem Bio Defense (JPEO-CBD).

	FY 2005	FY 2006	FY 2007
Mission-Adaptable Chemical Sensors (MACS)	5.500	10.652	7.700

(U) At present, chemical sensors are unable to combine sensitivity (parts-per-trillion) and selectivity (unambiguous identification of molecular species) with low false alarm rate. This effort will develop a sensor, based upon rotational spectroscopy of gases that will have superior capability in all categories; it will achieve the highest possible sensitivity (parts-per-trillion) for unambiguous detection of all chemical species. A preliminary blind test showed complete and unambiguous identification with a sampling time of one second and a false alarm probability below 0.001%. At present, the program has investigated the nature of the atmospheric background "clutter" at the parts per billion (ppb) level and below to enable the identification of target signatures at highest sensitivity. The program will focus on reduction of size and simplicity of function to achieve portability and simultaneous detection of a large number (hundreds) of species. The capabilities will far surpass all other current sensors.

(U) Program Plans:

- Design and build a table top form factor, high-sensitivity sensor system and demonstrate its performance in a high-clutter atmospheric background.
- Demonstrate fractionation and related improvements to the system for simultaneous identification of multiple species in seconds.
- Refine table top form factor design and build a fully portable, high-sensitivity sensor system.
- Demonstrate the fully portable, high-sensitivity sensor system in a high-clutter atmospheric background.

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	FY 2005	FY 2006	FY 2007
Center for Water Security	1.000	0.000	0.000

(U) Program Plans:

- Established the Center at the University Wisconsin-Milwaukee through engaging essential technical personnel, acquiring state-of-the-art instrumentation dedicated to researching new and highly effective methods of water quality sensing.
- Continued to develop the use of the new methodologies through partnerships with public and private sector agencies to address water security issues related to civilian and military needs.

	FY 2005	FY 2006	FY 2007
Asymmetrical Products for BWD	2.000	1.300	0.000

(U) Program Plans:

- Continue to develop a technical approach to induce mucosal immunity against BioWarfare (BW) pathogens. Modeled and synthesized a cytokine-based family of compounds that stimulates mucosal immunity.
- Identify likely cytokine molecules and their combinations that result in resistance to pathogens.

	FY 2005	FY 2006	FY 2007
Center for Tropical Disease Research and Training	2.800	0.000	0.000

(U) Program Plans:

- Continued to examine *Leishmania* parasites to identify both *Leishmania* and sand fly molecules that may be useful in developing a protective vaccine against leishmaniasis, a serious disease affecting soldiers returning home from Iraq.

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	FY 2005	FY 2006	FY 2007
New Approaches to Weaponized Infections Organisms	1.000	0.000	0.000

(U) Program Plans:
- Evaluated potential new targets for antibiotics based on enzymes.

	FY 2005	FY 2006	FY 2007
Noninvasive Biomodulation	2.600	2.100	0.000

(U) Program Plans:
- Demonstrated new non-invasive approaches to biomodulation.

	FY 2005	FY 2006	FY 2007
Antimicrobial Research Program	2.100	0.000	0.000

(U) Program Plans:
- Developed new approaches for antimicrobial compounds.

	FY 2005	FY 2006	FY 2007
Bioscience Center for Informatics	1.000	0.000	0.000

(U) Program Plans:
- Developed new mathematical concepts to attack large biological data sets.

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	FY 2005	FY 2006	FY 2007
Chemically Programmable Immunity	1.000	0.000	0.000

(U) Program Plans:
- Demonstrated the use of novel strategies to usurp the natural immune system to fight and remove pathogens.

	FY 2005	FY 2006	FY 2007
Specific Gas Detector	0.000	0.500	0.000

(U) Program Plans:
- Develop new approaches for the detection of specific gases.

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

	FY 2005	FY 2006	FY 2007
Previous President's Budget	159.567	145.354	144.050
Current Budget	155.360	148.108	112.242
Total Adjustments	-4.207	2.754	-31.808
Congressional program reductions	-0.123	-2.146	
Congressional increases	0.000	4.900	
Reprogrammings	0.000		
SBIR/STTR transfer	-4.084		

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

FY 2005	Decrease reflects the DOE transfer directed by P.L. 108-447 and the SBIR/STTR transfer.
FY 2006	Increase reflects four congressional adds for biological defense enhancements, gas detection and noninvasive biomodulation offset by undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Decrease reflects the completion and transfer of the Immune Building program, completion of the TIGER and SSBA sensor systems, and repricing of several countermeasure, diagnostic, and sensor programs.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	316.673	346.076	383.680	448.165	493.591	509.935	476.565
Naval Warfare Technology TT-03	41.295	52.344	38.497	31.443	30.190	30.190	30.190
Advanced Land Systems Technology TT-04	64.065	71.306	74.299	99.927	116.365	122.279	129.109
Advanced Tactical Technology TT-06	107.096	97.375	111.706	115.074	125.256	125.256	125.256
Aeronautics Technology TT-07	47.876	58.290	78.027	84.462	100.452	105.752	80.752
Network Centric Enabling Technology TT-13	56.341	66.761	81.151	117.259	121.328	126.458	111.258

(U) Mission Description:

(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, Advanced Tactical Technology, Aeronautics Technology and Network Centric Enabling technologies.

(U) The Naval Warfare Technology project develops advanced enabling technologies for a broad range of naval requirements. The Friction Drag Reduction program will develop friction drag reduction technologies for surface ships and submersibles. The Hypersonics Flight Demonstration program is a joint Navy/DARPA effort that will develop and demonstrate advanced technologies for hypersonic flight. The High Efficiency Distributed Lighting program will change the fundamental design for lighting systems, resulting in increased warship maintainability and survivability. The Surface Warfare Automated Shiphandling program will develop technologies to increase survivability and operational effectiveness of small and medium surface vessels in rough seas. New areas to be investigated are ship self defense techniques, novel underwater propulsion modalities, vessels for estuary and riverine operations and predictive tools for small craft hydrodynamic design.

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(U) The Advanced Land Systems Technology project is developing technologies for enhancing the U.S. military's effectiveness and survivability in operations ranging from operations against traditional threats and emerging irregular threats that can employ disruptive or catastrophic capabilities. The Networking Extreme Environments program will address integration of ultra wide band communications and sensor systems. The Novel Sensors for Force Protection program is developing technologies to protect U.S. warfighters such as using a variety of fused multi-spectral techniques to identify the presence of people inside of buildings and chemical sensors capable of providing an advanced warning of the presence of enemy troops. The Dynamic Optical Tags program will develop new tagging, tracking and location capabilities for U.S. forces. The Guided Projectiles program will develop highly maneuverable gun-launched projectiles for defense against ground and air threats. The Compact Military Engines program will apply innovative ideas for engine design to produce performance gains not obtainable by further refinement of conventional designs. Two new initiatives, Sweeper and Maneuver and Control on the Urban Battlefield will address technologies for building clearing robots and access tools for use in tactical urban operations.

(U) The Advanced Tactical Technology project is exploring the application of compact and solid state lasers; high performance computational algorithms to enhance signal processing, target recognition and tracking, electromagnetic propagation, and processing of advanced materials and microelectronics; precision optics components for critical DoD applications; aerospace electronic warfare systems; new tactical systems for enhanced air vehicle survivability, advanced airbreathing weapons, and enabling technologies for advanced space systems; and a Training Superiority program that will create revolutionary new training techniques.

(U) The Aeronautics Technology project explores technologies to reduce costs associated with advanced aeronautical systems and provide revolutionary new capabilities for current and projected military mission requirements. This project funds development of micro adaptive flow control technologies; small-scale propulsion system concepts; and a high-strength, low structural weight airlift vehicle designed to control its buoyant lift independently of off-board ballast. New areas to be investigated are reusable hypersonic vehicles; novel helicopter blade designs that reduce acoustic signature; small, low cost high endurance UAV's capable of destroying most enemy UAV's; and short distance take off and landing of fixed wing aircraft.

(U) The Network Centric Enabling Technology project funds sensor, signal processing, detection, tracking and target identification technology development required for true network-centric tactical operations. Technologies developed in this project will enable localized, distributed and cross-platform collaborative processing so that networks of sensors can rapidly adapt to changing force mixes, communications connectivity and

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mission objectives. Operational benefits will be smaller forward deployment of image and signal analysts, consistent integration of target and environment information, and flexible operational tactics and procedures for finding evasive targets in difficult environments.

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

	FY 2005	FY 2006	FY 2007
Previous President's Budget	327.825	361.562	418.818
Current Budget	316.673	346.076	383.680
Total Adjustment	-11.152	-15.486	-35.138
Congressional program reductions	-.0261	-26.886	
Congressional increases	0.000	11.400	
Reprogrammings	-2.500		
SBIR/STTR transfer	-8.391		

(U) Change Summary Explanation:

FY 2005	Decrease reflects SBIR/STTR transfer, a DOE transfer for P.L. 108-447 and a below threshold reprogramming.
FY 2006	Decrease reflects the $20M congressional reduction to the Walrus program, FFRDC reduction, undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission offset by congressional adds to R31 systems, CEROS, MESH- Enabled Architecture, Counter Sniper/RPG and Enhancement of Communications and Telemetry Support Equipment.
FY 2007	Decrease reflects reduced funding for the Friction Drag Reduction in Project TT-03, Naval Warfare Technology, and termination of the Walrus effort in Project TT-07, Advanced Aeronautics Technology.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Naval Warfare Technology TT-03	41.295	52.344	38.497	31.443	30.190	30.190	30.190

(U) Mission Description:

(U) The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. Enabling and novel technologies include concepts for expanding the envelope of operational naval capabilities such as drag reduction, hypersonic missiles, logistically friendly distributed lighting systems, ship self defense techniques, novel underwater propulsion modalities, vessels for estuary and riverine operations, acoustic anti-submarine warfare and predictive tools for small craft hydrodynamic design.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Friction Drag Reduction	3.142	13.009	5.125

(U) The Friction Drag Reduction program will develop and demonstrate physics-based, predictive engineering design tools that will yield additive-based friction drag reduction on Navy surface ships that exceed the cost of implementation. Such a capability would result in decreases in fuel usage, increases in burst speed, and enhancements in vehicle range and endurance. To date, the program has developed the capability to predict from first-principles how turbulent flows are modified by the presence of polymers and microbubbles. These first-principles models were validated with small-scale physical experiments and initial tests in a large scale facility at ship-relevant scales. This predictive capability will be extended and tested at large scales, using an optimized injector in a blind-test of the prediction and design tool in the large scale facility. The predictive capabilities will be validated using large-scale experiments conducted on a 13 meter long flat plate at the U.S. Navy's William B. Morgan Large Cavitation Channel. Finally, these large-scale predictive models will be used to design an optimal implementation of additive-based drag reduction technology for a realistic at-sea test (e.g., small surface ship).

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(U) Program Plans:

- Refined multi-scale modeling capability incorporating the physics learned in large-scale tests into engineering codes for use as reliably predictive design tools.
- Conducted a large scale micro-bubble experiment to provide high-quality data at large scales in order to validate the models.
- Conducted a large scale test of polymer injection to provide high-quality data at large scales in order to validate the models.
- Finalized design of refined injection system for additional large scale micro-bubble testing.
- Initiated second series of micro-bubble tests with refined injection system design.
- Completed preliminary design of refined injection system for additional large scale polymer testing.
- Verify predictive capabilities of microbubble and polymer models.

	FY 2005	FY 2006	FY 2007
Surface Warfare Automated Shiphandling (SWASH)	1.900	4.914	3.728

(U) The Surface Warfare Automated Shiphandling (SWASH) program will develop and demonstrate technologies to increase survivability and operational effectiveness of small and medium naval surface vessels in rough seas. Currently, vessels are at the mercy of ocean waves, and when waves become sufficiently large, damage and capsizing can occur. SWASH will enable safe operations in an expanded sea state envelope. SWASH combines detailed sensing and wave prediction of the local sea surface with improved understanding of vessel dynamics in a control system that provides optimum course and speed to the vessel's rudder and engines. SWASH offers the potential to reduce injuries to crew and passengers as well as damage to vessels caused by high waves. In addition, SWASH is an enabling technology for unmanned surface vessels (USVs), which will be a component of the modules for the Navy's new Littoral Combat Ships (LCS). SWASH will increase the survivability and operability of USVs in rough seas, and can provide inputs to the LCS steering system to make USV launch and recovery faster and safer. Medium manned vessels, such as LCS, DD(X), and current classes, will benefit from the more detailed knowledge of wave fields that will be developed in the SWASH program. Sophisticated steering strategies can reduce damage to the vessels caused by high waves, and improve human performance by reducing vessel motions.

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(U) Program Plans:
- Refine prediction capability for ocean wave fields.
- Improve models of small craft dynamics in high sea states.
- Develop control algorithms for wave avoidance.
- Test control schemes in "virtual ocean" environment and scale model tests, as well as at-sea testing.

	FY 2005	FY 2006	FY 2007
Hypersonics Flight Demonstration (HyFly)	19.615	11.882	9.476

(U) The Hypersonics Flight Demonstration program (HyFly) will develop and demonstrate advanced technologies for hypersonic flight. Flight-testing will be initiated early in the program 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 vehicle performance leading to a tactical surface launched missile range of 600 nautical miles. Specifically the program will demonstrate an F-15 launched missile configuration with a range of 400 nautical miles with a block speed of 4,400 feet per sec, maximum sustainable cruise speed in excess of Mach 6, and the ability to accurately terminate the missile on a GPS guided impact target. Technical challenges include the scramjet propulsion system, lightweight, high-temperature materials for both aerodynamic and propulsion structures, and guidance and control in the hypersonic flight regime. Recently demonstrated performance in ground testing of the dual combustion ramjet engine coupled with advances in high temperature, lightweight aerospace materials are enabling technologies for this program. The core program will focus on development and demonstration of capabilities requisite for an operational weapon. A separate effort will be performed in parallel to demonstrate advanced propulsion technologies and develop low-cost test techniques. DARPA and the Navy have established a joint program to pursue areas of the hypersonics program that would be relevant to maritime applications.

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(U) Program Plans:

– Performed preliminary and detailed design efforts and supporting materials-structural demonstrations.
– Conducted freejet aero-propulsion testing of the heavyweight vehicle configuration.
– Performed ground test verification (static firing) of supersonic low altitude target boosters.
– Performed advanced combustion systems proof of concept testing in gun-launched test range.
– Conducted ballistic and free-flight subscale testing of advanced engine technologies.
– Conduct captive carry, drop, boost performance and boost separation flight tests.
– Perform vehicle subsystems verification testing.
– Conduct flight weight vehicle environmental testing.
– Conduct flight weight vehicle freejet performance and durability testing.
– Conduct initial, low flight Mach (~Mach 4.0) flight-testing.
– Demonstrate Mach 6.0 cruise and extended range (400 nm).

	FY 2005	FY 2006	FY 2007
High Efficiency Distributed Lighting (HEDLight)	5.672	2.354	2.000

(U) The High Efficiency Distributed Lighting (HEDLight) program seeks to fundamentally change the design for lighting systems on U. S. military platforms to increase survivability, deployability, and maintainability. Current lighting systems use electrical distribution and the generation of light at the point-of-use. HEDLight remote source lighting uses centralized light generation and optically transports the light to the point-of-use. This allows the lighting system electrical circuitry and wiring to be concentrated, protected, and removed to the interior of the warship, thereby removing a source of vulnerability from the outer-envelope. Critical metrics that are necessary for the successful implementation of HEDLight are system efficiency, weight, and control of the illumination pattern. The technical areas key to the success of the HEDLight program include the development of compact, high-efficiency, full-spectrum light sources; high-efficiency coupling optics; high-efficiency, integrated optical-fiber luminaries; and integrated illuminator engines that effectively combine the light source, the optical coupler, and fiber-luminaire.

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(U) Program Plans:
- Develop high efficiency full-spectrum light sources.
- Develop high efficiency optical coupling mechanisms.
- Develop high efficiency fiber-luminaries for distributed light transport.
- Develop an integrated high efficiency distributed lighting illuminator.
- Demonstrate a limited scale HEDLight system installed on a U.S. Navy ship.

	FY 2005	FY 2006	FY 2007
Center of Excellence for Research in Ocean Sciences (CEROS)	7.000	6.000	0.000

(U) The Center of Excellence for Research in Ocean Sciences (CEROS) encourages leading edge research and development in ocean sciences, by involving highly specialized small businesses with recognized expertise in ocean related research, and providing access to the ocean sciences expertise of the University of Hawaii. Major research areas of interest have included shallow water surveillance technologies, ocean environmental preservation, new ocean platform and ship concepts, ocean measurement instrumentation, and unique properties of the deep ocean environment.

(U) Program Plans:
- Select projects for funding.
- Contract selected projects and monitor progress of ocean related technologies of high interest to the DoD.
- Transition appropriate products to military use.

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	FY 2005	FY 2006	FY 2007
Acoustic Arrays for Torpedo Defense	3.966	3.760	2.000

(U) The Navy's Sea Power 21 vision requires future naval forces to have assured access to littoral waters. Sea Strike forces must have the ability to conduct maritime operations in the presence of diesel submarine threats and surface craft capable of launching torpedoes. The Acoustic Arrays for Torpedo Defense program will demonstrate the feasibility of using an array of transducers to form a destructive pressure pulse capable of disabling an enemy's torpedo. Of critical importance is the ability to accurately predict non-linear pressure pulse propagation effects and corresponding timing delays used during pressure pulse generation and beamforming. Additionally, the beamformed pressure pulse must be of sufficient amplitude and duration to destroy a torpedo at tactically significant ranges.

(U) Program Plans:
- Conducted non-linear pressure pulse propagation modeling and assessed projected system performance.
- Designed, developed and tested a single transducer.
- Design, develop, and test prototype transducer array.
- Conduct prototype system testing.

	FY 2005	FY 2006	FY 2007
Unique Propulsion Techniques (formerly Ribbon Fin Propulsion)	0.000	2.120	3.273

(U) The Unique Propulsion Techniques program will develop a novel underwater propulsion technology for Unmanned Underwater Vehicles (UUV) and other underwater platforms that require high maneuverability at low velocities. Electric eels using ribbon fin propulsion may be generating traveling chains of ring vortices, which give more momentum transfer than simply pushing the same quantity of fluid with no structure. The objective of the program is to develop a ribbon fin propulsion system and demonstrate the increased low velocity power efficiency and maneuverability of an actual underwater platform. The fundamental technical challenges include 1) determining if the traveling wave is structured

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to maximize thrust, 2) determining the structure of the fluid flow imparted by the ribbon fin, 3) determining how to implement a flexible ribbon structure with sufficient power and controllability to be useful, and 4) determining how to attach such a structure to a rigid body and integrate it with other control surfaces to gain additional degrees of freedom.

(U) Program Plans:

- Accurately model the physics of ribbon fin propulsion and create predictive design tools.
- Design and demonstrate a ribbon fin propulsion system on an appropriately scaled surrogate platform.

	FY 2005	FY 2006	FY 2007
Riverine Crawler Underwater Vehicle	0.000	3.120	3.613

(U) The Riverine Crawler Underwater Vehicle program will study means of operating in challenging conditions of obstructions, turbidity and current such as in rivers and harbors by an unmanned submerged craft. Novel means of navigation, propulsion and sensing will be required to operate autonomously in such environments.

(U) The scope of this program will be to explore the potential concepts and the technologies to perform these missions. The effort will identify the promising vehicle types and examine the system and/or component element technologies required to support these vehicles.

(U) Program Plans:

- Perform concept of operations (CONOPS) studies; set the basis of the technology survey, vehicle concept applicability evaluation and the process for identifying vehicle system and component technology concepts.
- Identify technologies to address various challenges that a set of defined vehicle types and sensor payloads must face in the riverine environment and what possible forms the vehicle could take in order to address each of the mission challenges.

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	FY 2005	FY 2006	FY 2007
Fast Boat (formerly Small Craft Advanced Hydrodynamic Design)	0.000	5.185	3.582

(U) The Fast Boat program will design, build, and demonstrate one or more boats with threshold speeds of 70 knots and an objective speed of 100 knots in high sea states with a ride quality that is a significant improvement over existing boats. The designs will be tailored to special operations and will be sized for the missions of boats used by the special operations community. Boats produced in this program could also be used to support the Navy's Riverine mission.

(U) Today's boats are capable of high speed in calm water but not in moderate or high sea states. Poor ride quality in existing boats used for special operations results in a very high incidence of crew and passenger injuries in moderate or high sea states. The Fast Boat program will demonstrate designs capable of both high speed and good ride quality in sea states 3-5 and will investigate the operational benefit of high speed in special operations.

(U) Program Plans:

- Complete trade systems and preliminary design.
- Fabricate one or more full-scale demonstrators.
- Conduct performance demonstrations in low, moderate, and high sea states.
- Complete a limited user test in which the operational value of speed is explored and quantified.

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	FY 2005	FY 2006	FY 2007
Super-Fast Submerged Transport (Underwater Express)	0.000	0.000	3.500

(U) The Super-Fast Submerged Transport (Underwater Express) program will demonstrate the first application of manned vehicle supercavitation enabling high speed transport of personnel and/or supplies. The inherent advantages of traveling underwater are: ability to transit clandestinely, no radar or visible signature, and avoidance of rough sea conditions that may limit or deny mission execution. Supercavitation places the vehicle inside a cavity where vapor replaces the water, and viscosity is reduced by orders of magnitude, thus reducing the power requirement dramatically. This program will design an underwater vehicle that can operate close to the surface where cavitation can occur more easily (lower vapor pressure), and, by augmenting the cavitation with forced ventilation, a marked decrease in cavitation speed is possible. Innovative failsafe control will be required for stability and maneuverability at speed.

(U) Program Plans:

- Develop models and simulations to predict cavity and cavitator performance.
- Design a vehicle concept.
- Conduct subscale testing in a controlled facility.
- Design, fabricate and test a scaled prototype vehicle.
- Test in wire guided pond for failure modes and responses.
- Analyze against metrics for speed/power and stability.
- Incorporate model test results into design.

	FY 2005	FY 2006	FY 2007
Wideview	0.000	0.000	2.200

(U) This program will exploit a technology used successfully by the underwater acoustic community and convert it to give tactical aerial vehicles the ability to continuously detect, locate and track battlefield sounds (such as sniper firing) over a whole 360° field of view.

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(U) Program Plans:
- Measure airborne towed array noise.
- Adapt current capabilities from water to the higher speeds of air vehicles. Perform system analysis to assure compatibility of towed arrays with UAV performance.
- Develop acoustic models through computational techniques and limited airborne testing to account for background clutter. Assure fires detection range at least 10km from UAV at 5,000 feet, and the tracking of combat vehicle noise at a similar range.
- Develop a prototype system.

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

	FY 2005	FY 2006	FY 2007
Hypersonics Flight Demonstration PE 0602114N, PE 0603114N, PE 0603123N, Navy, Office of Naval Research	15.000	11.300	2.200

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Advanced Land Systems Technology TT-04	64.065	71.306	74.299	99.927	116.365	122.279	129.109

(U) Mission Description:

(U) This project is developing technologies for enhancing U.S. military effectiveness and survivability in operations ranging from traditional threats to military operations against irregular forces that can employ disruptive or catastrophic capabilities, or disrupt stabilization operations. The 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 programs: Novel Sensors for Force Protection; Dynamic Optical Tags (DOTS); Guided Projectiles; Networking Extreme Environments (NetEx); MAgneto Hydrodynamic Explosives Munition (MAHEM); Compact Military Engines; Crosshairs; Improved Explosives; Agile Interceptor; Counter Improvised Explosives Laboratory (CIEL); National Cyber Security Center; Stimulated Isomer Energy Release (SIER); Vertical Infiltration, Persistent Extraction Robot; Sweeper; and Maneuver and Control on the Urban Battlefield.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Novel Sensors for Force Protection	10.910	12.459	15.352

(U) The Novel Sensors for Force Protection program is exploring and developing a variety of novel methods that will contribute to enhanced protection of U.S. warfighters and address hostile situations encountered by U.S. warfighters in the Global War on Terrorism, Operation Enduring Freedom and Operation Iraqi Freedom. The motivation behind all of the programs is to reduce the exposure of U.S. warfighters when they are operating in disadvantageous territory, especially those complex settings (densely populated and structured areas, multi-storied buildings, etc.) typically found in urban settings. The Novel Sensors program consists of the Unique Signature Detection Project (formerly known as the Odortype Detection program), the Enemy Dismount Intrusion Detection Project, the Urban Vision Project, and congressionally added funds for Tactical Awareness for Friend or Foe.

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(U) The objective of the Unique Signature Detection program is to determine by means of a well-developed scientific methodology whether there are unique signatures in emanations that can be used to identify and distinguish specific high-level-of-interest individuals within groups of enemy troops or combatants, and if so, to develop enabling technology for detecting and identifying those specific signatures. The program consists of an interdisciplinary team of performers using state-of-the-art techniques to evaluate the statistical, biological and chemical nature of individual emanations. Once the nature of the chemosignal has been characterized, performers will determine the impact of non-genetic factors (e.g., diet, stress, health, age) on the signal in order to determine whether the signal can be robustly extracted from a complex and varied chemical background. If an exploitable robust signature is identified, the program will then pursue detector development.

(U) The Enemy Dismount Intrusion Detection program will develop a chemical sensor that is capable of providing an advanced warning of the presence of enemy troops or combatants by detecting the chemical emissions or pattern of emissions that are common to all humans, but are otherwise not ordinarily encountered in the environment. This program will leverage capabilities found in nature to recognize and locate the volatile chemicals that are the most reliable indicator of the presence of enemy troops or combatants leading to the development of a sensor and detection scheme that will be capable and robust against false alarms. This detection capability would replace land mines as a way to provide advanced threat warning of approaching enemy combatants to troops involved in perimeter defense and similar operations.

(U) The goal of the Urban Vision program is to enable the warfighter to ‘see’ movers within a building using a variety of fused multi-spectral techniques. The objective is to develop a necessary and sufficient number of sensor breadboards that can demonstrate the capability to the user community. The application is in-building take-down operations, where the user enters the building through the roof. The sensors will be placed on the roof to give information on the number and location of occupants in the floor immediately below. The sensors must be small and light weight. The system must operate with a minimal number of sensors (the goal is four). Technical challenges include understanding the fundamental physics limitations of various techniques, fusion and developing a combined sensor and networked communications transceivers with required size, weight and power for candidate platforms.

(U) Program Plans:
- Unique Signature Detection
  - Identify the chemical make-up of the Major Histocompatibility Complex (MHC)-determined unique signatures.
  - Examine the chemistry and impact of non-genetic background signals and develop receiver operator curves (ROC) for performance.

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  - Design detectors that are capable of identifying high-level-of-interest individuals within groups of enemy troops or combatants through unique, specific signatures with high reliability.

- Enemy Dismount Intrusion Detection
  - Determine the required performance of a chemical emission sensor as part of a system of sensors in a perimeter defense.
  - Determine the chemical emissions that are unique to humans and therefore to all enemy dismounted troops and combatants.
  - Determine the specificity of the human chemosignal in a variety of complex backgrounds.
  - Design detectors capable of reliably indicating the presence of enemy dismounted troops and combatants with a low false alarm rate.

- Urban Vision
  - Design, develop, and evaluate an initial (fixed placement) multi-static multi-frequency dielectric imaging array test system.
  - Establish baseline system performance parameters for spatial resolution and dielectric differentiation.
  - Develop algorithms for inverting the multi-static imaging data to reveal the interior structure and distribution of objects within the structure, and the coarse categorization of those objects with sizes typically associated with enemy troops or combatants and dielectric characteristics.
  - Design, develop, and demonstrate an array multi-static dielectric tomography imaging system.

	FY 2005	FY 2006	FY 2007
Dynamic Optical Tags (DOTS)	8.819	10.875	7.145

(U) Based on the technical successes and demonstrated operational relevance of DARPA's now completed Optical Tags program, the Dynamic Optical Tags and Sticky Flares programs seek to create new tagging, tracking, designating, and locating capabilities for U.S. forces. These programs will develop optical tagging, interrogation, and designation technologies that will enable small devices such as environmentally robust, retro reflector-based tags and highly-visible designators that can be read by both handheld and airborne sensors at significant ranges. These tags can be used for unique, non-radio frequency (RF) identification of items of interest, monitoring tactical areas for disturbance from personnel and

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vehicles, and designating targets in complex environments. The identification tags also will be capable of providing persistent two-way communications for both tactical and logistics operations.

(U) Program Plans:
- Identified promising retro reflecting and designating techniques.
- Developed most promising retro reflecting and designating techniques into tag design.
- Develop novel emplacement technologies.
- Develop handheld and airborne interrogation systems.
- Integrate and test components in a fully functional configuration.

	FY 2005	FY 2006	FY 2007
Guided Projectiles	16.078	18.572	12.893

(U) The Guided Projectiles program is developing and demonstrating highly maneuverable gun-launched projectiles, and associated fire control and launch systems for employment against critical enemy infrastructure and point targets, such as command, control and communication nodes and radars. This program will develop enabling technologies to give U.S. warfighters the ability to allow weapons platforms, such as mortars, to receive updated target information from other munitions or sense target changes on their own. Based upon this information, the platforms can adjust course in flight to prosecute highly-mobile, time-sensitive targets such as those encountered during Operation Enduring Freedom and reduce the potential for collateral damage. This program will adapt recent advances in communications, computers, sensing and propellants/explosives to demonstrate significant leaps in combat capability. The technologies being developed will demonstrate the increased combat effectiveness and the reliability of distributed, collaborative processing and mission execution.

(U) The program will develop a low-cost, non-imaging optical seeker/guidance unit exploiting technology development in the visible and infrared spectrum that will replace the current 60mm mortar fuse to improve firing precision. Additionally, research will be done with explosives to improve the effectiveness of 60mm explosive rounds. The goal is to develop a 60mm projectile with the effectiveness of a 105mm high explosive projectile.

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(U) The program also developed small aperture, geolocation capabilities for a new-class of anti-radiation weaponry and enabled a suite of weapon sensor and guidance systems that homed and guided on the RF energy emitted by enemy forces. The potential applications include ground-to-ground, air-to-ground, and ground-to-air weapons all using similar RF sensor guidance technology. The result of this effort could create a passive, all-weather, and inexpensive precision targeting capability for precision and area suppression weapons and counter enemy signals camouflage, concealment and detection efforts. The initial effort focused on providing an RF sensor, guidance and warhead package capable of being fired out of an 81mm mortar.

(U) A portion of this program will investigate supersonic interceptors that provide high rate, multiple engagement defenses of critical tactical or strategic assets, including naval surface ships, airborne intelligence, surveillances, and reconnaissance platforms, and fixed radar/command, control and communications sites. Supersonic flight control for aggressively maneuvering medium caliber projectiles will be developed and integrated into advanced projectile designs to achieve lateral accelerations far exceeding those achieved by “course-correcting” projectiles.

(U) Program Plans:

- Developed, modeled and validated supersonic flight control technologies.
- Conducted preliminary development and evaluation of key subsystem technologies.
- Performed initial flight demonstrations and target acquisition demonstrations.
- Fabricated and tested critical subsystems for projectile maneuvering, guidance and data transmission.
- Develop mortar seeker using an array of non-imaging optical lenses.
- Develop small and responsive mortar guidance/control/steering fin system.
- Integrate seeker with guidance/control/steering system into a unit that replaces the current fuse on the 60mm high explosive mortar.
- Develop designator systems that provide visible and infrared light emissions from a target compatible with the optical/guidance unit.
- Demonstrate tube launch of 60mm optically guided mortar round and optical designating system in conjunction with USMC.

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	FY 2005	FY 2006	FY 2007
Networking Extreme Environments (NetEx)	6.801	4.978	4.907

(U) The Networking in Extreme Environments (NetEx) program will create a wireless networking technology for the military user that will enable robust connectivity in harsh environments (for example, areas prone to multipath interference such as urban settings where buildings and other structures cause RF energy to “bounce” off, in and amongst the buildings/structures) and support development of new and emerging sensor and communication systems. This program will develop an improved physical layer for networked communications based on a family of new ultra wideband (UWB) devices. These devices will enable reliable and efficient operations in harsh environments by exploiting the unique properties of UWB systems that allow them to work in a dense multi-path environment and to function as both a sensor and communications device. The program will adapt new and emerging ad-hoc routing protocols and multiple access schemes to take advantage of the unique properties of UWB to communicate in harsh environments, to very accurately resolve range, and to act as a radar based sensor.

(U) Program Plans:
- Characterized the effect of UWB system operation on military radio frequency receivers.
- Determined the thresholds of interference of UWB, which are caused by legacy equipment and methods by which it can be reduced.
- Developed an improved UWB physical layer.
- Develop a Tactical Voice/Data Radio (TVDR) with ranging.
- Develop a low bit rate sensor network with highly accurate geolocation.

	FY 2005	FY 2006	FY 2007
Magneto Hydrodynamic Explosive Munition (MAHEM)	4.180	4.880	5.135

(U) The Magneto Hydrodynamic Explosive Munition (MAHEM) program will demonstrate compressed magnetic flux generator (CMFG)-driven magnetohydrodynamically formed metal jets and self forging penetrators with significantly improved performance over explosively formed jets and fragments. Explosively formed jets (EFJ) and self forging penetrators (SFP) are used for precision strike against targets such as armored

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vehicles and reinforced structures. Current technology uses chemical explosive energy to form the jets and fragments. This is highly inefficient and requires precise machining of the metal liners from which the fragments and jets are formed. Generating multiple jets or fragments from a single explosive is difficult, and the timing of the multiple jets or fragments cannot be controlled. MAHEM offers the potential for higher efficiency, greater control, the ability to generate and accurately time multiple jets and fragments from a single charge, and the potential for aimable, multiple warheads with a much higher EFJ velocity, hence increased lethality and kill precision, than conventional EFJ/SFP. MAHEM could be packaged into a missile, projectile or other platform and delivered close to target for final engagement and kill. This could provide the warfighter with a means to address stressing missions such as: lightweight active self-protection for Future Combat Systems (FCS) vehicles (potential defeat mechanism for a kinetic energy round); counter armor (passive, reactive, and active); mine countermeasures; and anti-ship cruise missile final layer of defense.

(U) Program Plans:

– Refined magnetohydrodynamic models of MAHEM behavior.
– Continue capacitor-driven liner experiments to validate models.
– Complete single CMFG and MAHEM concept designs.
– Develop and conduct experiment demonstration of CMFG and CMFG-driven MAHEM.
– Develop MAHEM variants tailored to mission-specific requirements.

	FY 2005	FY 2006	FY 2007
Compact Military Engines	2.117	2.210	0.570

(U) As military systems become more mobile and autonomous, and able to carry out missions with greater endurance, they will require a new generation of engines that are lighter, more compact and consume less fuel. Further, the military is requiring that the new generation of engines consume only logistic fuel (JP-8). The Compact Military Engines Program will apply innovative ideas for engine design to produce performance gains not obtainable by further refinement of conventional designs. The ideas will, for example, eliminate heavy accessory components, such as the valve drive trains, and eliminate sources of lost power, such as piston side forces causing friction and thermal conduction through cylinder walls. The Compact Military Engines Program will address various engine types and diverse missions. A goal of the program is to decrease the

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size of mobile electric power generators by a factor of ten. Improvements to electric generators for hybrid electric vehicles will increase vehicle range and endurance.

(U) Program Plans:

- Completed concept design.
- Demonstrate critical technologies.
- Build and test prototype engines to demonstrate continuous operation at substantial power levels.
- Build and test prototype engines to demonstrate full performance.

	FY 2005	FY 2006	FY 2007
Crosshairs	4.060	7.370	9.000

(U) This program will develop methods and equipment to enable blue-team forces to detect, locate, and engage shooters and defeat a variety of common threats including bullets, Rocket Propelled Grenades (RPGs), Anti-Tank Guided Missiles (ATGMs), direct fired mortars, and Man Portable Air Defense Systems (MANPADS), both stationary and on the move. Threat identification and localization will be determined in sufficient time to enable automatic and man-in-the-loop response options. During Phase I the program will design, develop, and test candidate sensor systems. During Phase II, selected sensor systems will be demonstrated on a vehicle for on-the-move performance assessment, and will be integrated with self defense and response systems. Automated responses such as imaging for forensic and judicial evidence, rapid dissemination of location of combatants to allow both effective concealment and counterfire, slew to cue weapons, protective measures against RPGs followed by counterfire, and elimination of threats are also candidates for the operational system.

(U) The Concept of Operations is to provide HUMMWV-mounted detection and response systems that operate while on the move and a lightweight portable freestanding low power unit for platoons or squadrons while stationary. Techniques for supporting detection and false-alarm rate mitigation will be considered, including acoustic detection, optical, and radar detection. It is envisioned that the system will provide a significantly improved capability to detect and engage shooters during hostile and peacekeeping operations in both urban and non-urban environments. Technology challenges of particular interest are: low false rate algorithms, high speed reactive sensor techniques for a 360 degree

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azimuth and 60 degree elevation detection zone; robust data collection for tracking firing source; fast response and affordable solutions. The program will culminate with a series of prototype demonstrations of the system(s) in typical combat environments.

(U) Program Plans:
- Identify and develop ultra-fast sensors and algorithms to detect and track multiple threats in near real time.
- Perform component testing and conduct detection and shooter localization demonstrations.
- Analyze data and integrate sensors and response system with appropriate vehicle mounted counter-measures.
- Assess utility for dismounts.

	FY 2005	FY 2006	FY 2007
Improved Explosives	0.000	4.395	5.400

(U) The Improved Explosives program seeks to develop more effective explosive munitions. Such improvements are envisioned to provide U.S. small infantry units with organic firepower equal to light and medium artillery units. The explosives will provide U.S. forces with dominant capabilities in urban area operations by allowing the projection of superior destructive power against high-value targets. In addition, improved explosives will aid in denying sanctuary to enemy assets, including those hidden in armored, hardened or buried locations. The goal of the program is to develop systems that deliver three to five times more power (pound-per-pound) than conventional systems. The program will also evaluate and develop techniques for improving the effectiveness and efficiency of explosive energy. In addition, this effort will consider application of such improved explosives to wall/building breaching and improved explosive device (IED)/ordnance neutralization.

(U) Program Plans:
- Conduct initial studies, modeling and simulation to determine the feasibility of candidate technologies.
- Conduct experimental field tests to validate models.
- Design and develop improved munitions.

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	FY 2005	FY 2006	FY 2007
Agile Interceptor	0.000	4.000	5.330

(U) The Agile Interceptor program will develop and demonstrate a projectile system to protect limited areas (e.g. 1-2 km square) against mortar / artillery / rocket rounds, and potentially vehicles or helicopters from rocket propelled grenades, man portable air defense systems (MANPADS), and anti-armor rockets (e.g., TOW). The program will demonstrate an Agile Interceptor that will have the ability to maneuver very rapidly and with sufficient accuracy to engage the selected threat types while still remaining affordable. Relative to other options, the Agile Interceptor will be lower cost and will have significantly reduced collateral damage. The program will be multi-phased with frequent user reviews to ensure that the resulting products are meaningful and affordable. The program plan has various area and platform defense options that the Government will select after the initial phase of the program. The program will culminate with a series of prototype demonstrations of the capabilities in a realistic test environment.

(U) Program Plans:
- Define system architecture and constraints in conjunction with user / technical group.
- Develop and demonstrate critical technologies and evaluate to determine system effectiveness and cost.
- Initiate second phase to improve selected technologies and integrate them into the overall interceptor system.
- Demonstrate live fire intercept of mortars and other selected threats.

	FY 2005	FY 2006	FY 2007
Counter Improvised Explosives Laboratories (CIEL)	1.000	1.567	1.567

(U) Improvised explosives (IEs) are considered one of the most popular methods used by terrorist groups. Over the past 20 years, IEs have become very common due to their easy preparation and the high availability of raw materials. Efficient methods for detecting and neutralizing/desensitizing sensitive explosives labs in an urban environment will minimize interference with troop operations and minimize collateral damages. The goal of the Counter Improvised Explosives Laboratories (CIEL) program is to develop the infrastructure and

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methodology for novel chemo-sensors that will identify labs that are building IEs to a very high degree of specificity and reliability; and develop the infrastructure for tools for safe handling of improvised explosives and their mixtures.

(U) Program Plans:

- Develop a chemo-sensor that would provide a clear and fast identification of the target explosive.
- Identify a physical method that will neutralize bulk explosive materials.
- Conduct feasibility demonstrations.
- Optimize and demonstrate the sensor.

	FY 2005	FY 2006	FY 2007
National Cyber Security Center	1.000	0.000	0.000

(U) Future weapon systems for the tactical warfighter has increasingly relied upon the ability to transmit, receive, store and manipulate information. The security of this information is paramount and the techniques to accomplish this needed to be on the cutting edge to properly protect emerging, advanced weapons systems. The National Cyber Security Center will ensure that these capabilities are explored.

(U) Program Plans:

- Determined the feasibility of a National Cyber Security Center for advanced tactical weapon systems.

	FY 2005	FY 2006	FY 2007
Stimulated Isomer Energy Release (SIER)	4.000	0.000	0.000

(U) Nuclear isomers, such as hafnium 178m2, store in the nucleus 10,000 times as much energy per gram as TNT. The goal of the Stimulated Isomer Energy Release program was to develop a technique to control the release of this energy. The program demonstrated that as much energy can be released as is used to initiate the reaction (a breakeven experiment).

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(U) Program Plans:
- Determined if the hafnium isomer can be triggered with photons in the x-ray range that will release more than 50 times the energy input of the trigger.
- Identified a hafnium isomer production process that is affordable and cost effective.
- Developed a physics approach to a chain reaction for the hafnium isomer.

	FY 2005	FY 2006	FY 2007
Vertical Infiltration, Persistent Extraction Robot	5.100	0.000	0.000

(U) This program developed technologies to enable a robotic platform with high-degree-of-freedom mobility. System challenges to the development of the platform included: power generation, management and storage; locomotion; terrain and situational awareness; navigation and control; health and status monitoring; and position and configuration management. The program evaluated design approaches and concepts of operation for implementation and utilization of such a robotic platform.

(U) Program Plans:
- Performed risk reduction and feasibility studies of basic platform.
- Developed the integrated robotic system concept and conducted operator requirements study.
- Completed component testing to characterize system performance.

	FY 2005	FY 2006	FY 2007
Sweeper	0.000	0.000	3.500

(U) The goal of the Sweeper program is to design, develop, integrate and demonstrate the enabling technologies and system capabilities required to provide a prototype multi function building clearing robot for tactical urban operations use. Urban building clearing operations are among the most difficult and lethal missions that dismounted troops undertake. A mobile hardened robot utilizing solely non-lethal force will

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compel adversaries to vacate vertical urban structures. U.S. forces will be able to secure the perimeter of the structure while the Sweepers cause adversaries to vacate the structure and force them into a position of capture. The goal here is two fold: (1) demonstrate a hardened mobile human size (0.2 m^3) robot capable of robust operations inside multi story buildings (navigation and mobility and survivable from threat engagement) and (2) demonstrate various non-lethal capabilities separately and from the robot, to include target acquisition, target identification, and teleoperated and autonomous engagement. Non-lethal capabilities to be demonstrated could include RF, optical, acoustic, and malodorants. The Sweeper platforms would possess autonomous mapping capabilities in order to channel the adversary into directed routes of egress.

(U) Program Plans:

- Develop and demonstrate robust urban robots in terms of navigation and mobility and survivability.
- Develop and demonstrate robotic mapping and cooperative channelization via multi-robot employment.
- Develop and demonstrate non-lethal capabilities.
  - Sensor teleoperation and communications.
  - Sensor autonomous operations.
  - Sensor selection and target identification.
  - Modular modality demonstration of RF and optical non-lethal system.
  - Modular modality demonstration of acoustic non-lethal system.
  - Modular modality demonstration of malodorant non-lethal system.
- Demonstrate prototype system in a harsh (hostile fire) cluttered urban structure for warfighter experimentation and utility assessment.

	FY 2005	FY 2006	FY 2007
Maneuver and Control on the Urban Battlefield	0.000	0.000	3.500

(U) This program will develop new, high speed, lightweight, and portable tools including bar cutters, rotary cutters, 5-25 ton spreaders, jamb breakers, deployable personnel barriers, and rooftop access devices. The ultimate program goal is to reduce the weight of existing access tools by 80% as well as deliver new and unique capabilities such as direct and rapid rooftop access and rapidly deployed personnel barriers.

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(U) Program Plans:

– Develop lightweight mechanical power sources optimized for the unique duty cycle of equipment that is useful in an urban fight, i.e., 1-2 minute bursts interspersed with idle periods where silence may be at a premium. The goal is to reduce the weight of the energy storage and power conversion system by a factor of ten.
– Develop lightweight versions of access and population control tool end effectors including spreaders, cutters, jamb breakers, personnel barrier dispensers, and rooftop access systems by utilizing lightweight composites and ceramics. Active structural control may also be used to reduce structural mass.
– Combine the new power systems with the end effectors to create a set of unique tools optimized for use in urban combat.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Advanced Tactical Technology TT-06	107.096	97.375	111.706	115.074	125.256	125.256	125.256

(U) Mission Description:

(U) This project focuses on three broad technology areas: (a) compact, efficient, frequency-agile, diode-pumped, solid-state lasers for infrared countermeasures, laser radar, holographic laser sensors, communications, 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; and (c) enabling technologies for advanced aerospace systems and emerging payload delivery concepts. Additionally, this project will develop new tactical systems for enhanced air vehicle survivability, precision optics, electronic warfare, advanced air breathing weapons and training superiority systems. Studies under this project examine innovative approaches to non-invasive weapons detection, the use of laser and fiber-optic technologies to increase the survivability and lethality of existing systems, and the development of miniaturized and technologically advanced sensors, algorithms, and devices for monitoring assets.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
High Power Fiber Lasers	11.970	10.606	6.700

(U) The High Power Fiber Lasers program will develop and demonstrate single mode, single polarization fiber lasers with output powers greater than 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 electric power, in a compact footprint. For theater/area defense and self-protection of combat platforms, they will provide speed of light engagement and flexible response against cruise missiles, reconnaissance unmanned air vehicles (UAVs), and rockets.

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(U) Program Plans:
- Demonstrate greater than 100-watt single mode polarized output power from a single large mode-field area fiber.
- Demonstrate greater than 1 kilowatt single mode single polarization output power from a single large mode-field area fiber.
- Demonstrate 1 kw single mode output power from coherently combining the out-power from greater than ten fiber lasers.
- Demonstrate tens of kilowatt output power and capability to scale to greater than hundreds of kilowatts output power.

	FY 2005	FY 2006	FY 2007
High Powered FemtoSecond Laser Diodes	3.851	4.000	4.000

(U) The development of high power, reliable semiconductor laser diodes with tunable femtosecond pulse widths and highly scalable power levels, represents a technological advance of great potential utility to the Department of Defense. The successful demonstration of a compact, efficient, and powerful laser diode system could lead to incredible advances in micromachining, communications, ultra-short pulse spectroscopy, light detection and ranging (lidar), and directed energy applications.

(U) Program Plans:
- Model and evaluate concepts for ultra-short pulse, high irradiance laser diodes and select mode locked grating coupled surface emitting laser diodes (GCSEL) and semiconductor optical amplification using chirped pulse amplification and compression.
- Develop a series of GCSEL-based ultra-short pulse, ultra-high power lasers culminating in a 1 milliJoule/200 femtosecond per pulse laser system with a 10 kHz repetition rate that can fit into a shoebox. This represents a seven order of magnitude jump in the performance of semiconducting laser diodes.
- Demonstrate the ability of femtosecond laser to micromachine complex Defense parts.

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	FY 2005	FY 2006	FY 2007
Super High Efficiency Diode Sources (SHEDS)	9.888	4.288	4.000

(U) The goal of the SHEDS program is to develop laser diodes that are 80% efficient in converting electrical power to optical power. These will be used for supplying the optical power to ytterbium (Yb) and neodymium (Nd) solid state lasers operating near 1060 nanometers (nm). Such high efficiency laser pumps for these solid state lasers will lead to dramatic reductions in the size and weight of 100kW class diode pumped solid state lasers.

(U) Program Plans:

- Achieve 80% efficiency from single diode bars.
- Achieve a spectral range of 880nm to 980nm, the range for pumping directly into the upper laser level of Nd and Yb.
- Provide wavelength stabilization to prevent thermal drift of the diode bar wavelength outside of the range of high absorption of the laser transition.
- Achieve a power level of 480W/cm^2 per diode stack operating continuously.
- Achieve a peak power of 2000W/cm^2 for operating the stacks in a quasi-continuous wave (CW) mode with a duty cycle of no less than 25%.
- Achieve much more efficient diode stacks that will reduce the waste heat to one third of that generated by currently available diode bars.

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	FY 2005	FY 2006	FY 2007
High Energy Liquid Laser Area Defense System (HELLADS)	26.502	20.000	25.000

(U) The goal of the High Energy Liquid Laser Area Defense System (HELLADS) program is to develop a high-energy laser weapon system (~150 kW) with an order of magnitude reduction in weight compared to existing laser systems. With a weight goal of less than 5 kg/kW, HELLADS will enable high-energy lasers (HELs) to be integrated onto tactical aircraft and will significantly increase engagement ranges compared to ground-based systems.

(U) The HELLADS program has completed design of a revolutionary high energy laser that supports the goal of a lightweight and compact high energy laser weapon system. An objective system laser module with integrated power and thermal management will be fabricated and demonstrated at an output power of 15 kW. Based on the results of this demonstration, additional laser modules will be developed and integrated with a beam control subsystem to produce a 150 kW laser weapon system demonstrator. The performance of the demonstrator will be characterized in a laboratory environment.

(U) Program Plans:

- Develop and test a 15 kW objective system laser module with integrated power and thermal management subsystems.
- Complete preliminary design of a 150 kW laser weapon system.
- Complete detailed design and fabricate a 150 kW laser weapon system.
- Demonstrate performance of a 150 kW HEL system.

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	FY 2005	FY 2006	FY 2007
Laser Star	3.585	2.800	2.000

(U) The Laser Star program will investigate technologies and techniques for reducing the effect of atmospheric turbulence and other effects on the quality and clarity of images obtained by ground based telescopes. Current technology uses natural stars or an artificial star (called a "guide star") to provide a reference image from which the effects of the atmosphere can be computed and cancelled. Natural stars limit the pointing of the telescope. Artificial guide star technology currently makes use of either stratospheric Rayleigh backscatter or mesospheric sodium resonance scattering. These techniques have been utilized to successfully demonstrate strategies for wavefront compensation, but suffer from practical restrictions limiting operational utility. Rayleigh guide stars can be effectively generated to altitudes of 15 – 20 km, beyond which decreasing air densities reduce the backscatter to the point where unrealistic laser powers are required for useful return signal. The altitude is insufficient to provide full atmospheric sampling and suffers from sensor/target signal cancellation. Sodium resonance scattering is available to 90 km, which is an essentially complete atmosphere sample, but the return is monochromatic and cannot provide information about turbulence-induced absolute tilt. Laser Star technologies being developed to overcome these shortfalls include advanced multi-conjugate adaptive optics as well as nonlinear techniques.

(U) Program Plans:

- Complete concept design.
- Develop experiment design and procure long lead items.
- Conduct experiment.
- Analyze data and integrate with atmospheric compensation programs.

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	FY 2005	FY 2006	FY 2007
Coherent Communications, Imaging and Targeting	8.720	6.200	6.225

(U) The Coherent Communications, Imaging and Targeting (CCIT) program will provide powerful new capabilities for secure communication up-links (multi-giga bits per second), and aberration free 3-dimensional imaging (greater than 1000 kilometers) and targeting at very long ranges. Innovative design concepts for MEMs based Spatial Light Modulators (SLMs), which provide a quantum leap in digital wavefront control, and system integration of photonics and high-speed electronics will also be explored. The CCIT program will develop a scalable prototype system and perform basic demonstrations of communications and imaging from ground to space in a highly cluttered environment. The CCIT system will address the critical need for high-data-rate communications and imaging from land, sea and airborne platforms to space.

(U) The counter swarm offense and defense project will explore innovative concepts for defending high value ships and ports against multiple missiles, fast boats and airborne threats, and offense against multiple ground targets. New capabilities achieved by advances in SLMs and advances in modulation of high power fiber lasers allow for seamless transfer or hand-off of digital radar target acquisition data and continuous wave (cw) range angle imaging. By imprinting target locations on SLMs, multiple targets can be simultaneously designated in parallel with orthogonal codes consisting of spatial (amplitude) and temporal (phase) modulations. This allows for a single laser designator system to direct precision or semi-active laser guided munitions to a large number of incoming closely spaced threats. In addition, the program will seek to decrease degradation of accuracy or cross talk between guidance signals by assigning unique orthogonal codes to the interceptors to prevent spoofing.

(U) The high data-rate optical communications project will exploit the characteristics of CCIT SLMs to dynamically generate orbital angular momentum (OAM) of photons. Using SLMS to change the OAM of photons in real-time as opposed to simply modulating the amplitude of light waves allows for significant improvement in data carrying capacity. Concepts will be developed for secure laser communications by parametrically down converting OAM states that provide higher order entangled states compared to polarization entangled states. The program will also develop system level architectures for secure free space optical communication networks.

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(U) Program Plans:

- Develop 256 x 256 element spatial light modulators and integrated electronics, with pixel flatness of one fiftieth of a wavelength, 98 percent fill factor, eight bits of phase resolution and ten micro-second response time.
- Demonstrate low elevation ground-to-space imaging of objects.
- Concept development of target acquisition and hand-off to spatial light modulators (SLM) arrays.
- Design laser transmitter and receivers for digital target acquisition data and cw range angle imaging.
- Develop concepts for unambiguous resolution and detection of orbital angular momentum (OAM) states.
- Develop concepts for secure free space communications.

	FY 2005	FY 2006	FY 2007
High Performance Algorithm Development	10.323	11.471	13.000

(U) The programs in this area 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. They also cultivate theoretical breakthroughs in areas of basic mathematics having relevance to emerging Defense sciences and technologies. 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 digital representation and analysis of terrain and other geospatial data, efficient high fidelity scattering computations of radar scattering for predictive design and exploitation of radar cross sections, and efficient automatic mapping and optimization of signal processing kernels onto advanced Departmental computational hardware architectures.

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(U) Program Plans:

- Demonstrate efficient, accurate predictive algorithms for electromagnetic scattering from objects composed of inhomogeneous and anisotropic materials and including cracks, cavities gaps and thin edges; apply these codes to the accurate computation of radar cross section (RCS).
- Demonstrate efficient scattering codes capable of accurate computation of RCS for cruise-missile-sized vehicles with realistic material boundary conditions and full complexity components including high fidelity computational electromagnetic modeling capability for multisensor apertures and arrays.
- Develop innovative designs for analog systems with digital feedback control to extract high-level digital information from analog sources, such as digitized speech phonemes from acoustical signals or matched filter values from radar signals.
- Produce high-level algorithm-specification tools that will allow application domain experts (e.g., engineers in signal processing or fluid dynamics) to specify algorithmic Digital Signal Processing (DSP) library modules equal to expertly hand-tuned modules in one tenth the speed and power.
- Design and implement unified digital representations for map, terrain, and other geospatial data that will support highly efficient storage, query, and registration of geographical information from disparate sources.
- Demonstrate localized representations for high-altitude gravity data that provide the precision of current representations with ten percent of current storage requirements.
- Develop and test algorithms to exploit the presence of multiple scattering and clutter (e.g., foliage canopy) to enable imaging in the presence of multiple scattering and dispersion to enable image formation for acoustic, synthetic aperture radar, and active electro-optic sensors. Exploit multiple scattering and clutter to enable increased communication bandwidth at fixed power in acoustic and wireless applications.
- Create new system-level algorithms that are able to design and guarantee performance of complex systems while managing the uncertainty that is inherent in large, multiscale, highly interconnected systems where dynamics are important.
- Develop the required theoretical advances to establish rigorous foundations and methods in order to exploit recent discoveries of the presence of very low-dimensional intrinsic structure in large data sets of extrinsically high dimension.
- Develop techniques for self assembly of dynamic, non brittle, heterogeneous networks of surveillance and communications assets based upon mathematical inverse methods.

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	FY 2005	FY 2006	FY 2007
Integrated Sensing and Processing	8.865	5.000	5.000

(U) The Integrated Sensing and Processing program will open a new paradigm for application of mathematics to the design and operation of sensor/exploitation systems and networks of such systems by developing and applying novel optimization methodologies for integrating sensing, processing, and information exploitation functionality in 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 of hardware and software in a wide variety of systems, including agile adaptive arrays for missile seekers, unmanned air vehicles, and space-borne sensors; novel waveforms, adaptive waveform design and processing for object identification in dispersive and turbulent media; and novel approaches to multiplexed hyperspectral chemical/biochemical sensing systems.

(U) Program Plans:

- Develop and demonstrate new mathematical approaches to adaptive optimal control of tunable, mode-switchable, and configurable sensor systems/networks in which detection, estimation, classification, and tracking requirements determine sensing system operating parameters.
- Investigate extraction of high-level information directly from analog signals as part of the analog-to-digital conversion process, allowing joint optimization of traditionally separate sensing and processing functions.
- Develop real-time waveform design and scheduling strategies for ambiguity reduction and clutter mitigation in pulse diversity radar systems.
- Demonstrate feasibility of designs for quadrature thinning of two-dimensional conformal arrays that exhibit the same or better beam patterns than conventional arrays using fewer transmit/receive modules.
- Create new methods for processing sensor data and the design of sensors in which only non-redundant data is sampled to reduce sensor complexity, computational time and power consumption thereby dramatically improving sensor response.
- Develop information-theoretic metrics relating detection, estimation, classification, and tracking requirements to waveform structure in active sensing systems and use these metrics to devise new classes of mathematically optimal waveforms.

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	FY 2005	FY 2006	FY 2007
Training Superiority	12.563	15.831	24.271

(U) The Training Superiority program will change the paradigm for the way the military trains by creating new approaches to increase technical and physical competence as a result of revolutionary new training techniques developed in this program. Passive teaching approaches, including web-based training, will not succeed in instilling the skills and knowledge needed in the new land-battlefield, with higher demands on fewer soldiers, including the need to control and interact with highly technical unmanned systems. These new training approaches will include elements of human-tutor interactions and the emotional involvement of computer games coupled with the fidelity and feedback of Combat Training Center learning. In addition, these new training approaches will be linked into existing Service and Joint training systems to form a self-sustaining architecture, allowing continuous on-demand training anywhere at anytime.

(U) Program Plans:

- Develop, demonstrate and validate a continuously available, on-demand combat training system for all forces in the skills needed for successful performance across a comprehensive range of military operations, engagements and come-as-you-are wars.
- Develop, validate, demonstrate and deliver to military last-meter training systems that are focused on specific areas of performance requirements (e.g., “seabag sized” air mission trainer, tactical language instruction, convoy protection).
- Create an overarching training architecture populated with scalable multiple last-meter training systems that will allow any unit or individual, active, reserve, or civilian, to enter the virtual training world at any time, from any place, using existing hardware, and receive training tailored to specific individual training needs. Develop approaches to automatically insert lessons learned and incorporate realistic simulation of populations into that architecture.
- Exploit automated semantic analysis and multiplayer games to dramatically improve the training of teams and provide real-time feedback on team performance.
- Explore approaches for creating high-level cognitive competence through “training” of related non-cognitive functions.
- Exploit the use of multiplayer games to rapidly (weeks, not years) teach practical language and gestures to enhance interactions between soldiers and civilian populations. Investigate their use for improving the prediction of consequences of military activity.

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– Develop and demonstrate the use of computer simulations that can be updated with real world data in hours to allow truly realistic instant rehearsal of military operations to dramatically improve the planning and execution of those operations.

	FY 2005	FY 2006	FY 2007
Language and Speech Exploitation of Resources Advanced Concept Technology Demo	0.132	0.132	0.000

(U) DARPA's Compact Aids for Speech Translation (CAST) program developed speech translation technologies using handheld devices for military field operations. The Language and Speech Exploitation of Resources Advanced Concept Technology Demonstration (ACTD) program seeks to transition the CAST technology into the ACTD to support military utility assessments (MUAs). The application of information extraction techniques to speech translation has significantly advanced technology. This new technology will allow flexible and accurate translation of varying utterances without requiring recognition and translation of every word in the utterance.

(U) Program Plans:
- Installed a translator on small, readily available platforms (e.g., laptops, handhelds).
- Tested and evaluated language technology in the service labs.
- Transitioned the translator technology to the ACTD for MUAs.
- Continued to test and evaluate technology in operational context.

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	FY 2005	FY 2006	FY 2007
Air Laser	3.124	3.344	3.270

(U) The Air Laser program will investigate the potential for a high energy laser (HEL) concept based on direct diode pumping of liquid oxygen. If successful, the Air Laser could provide a safe, efficient kilowatt-to-megawatt-class HEL which combines the advantages of chemical and solid state lasers and minimizes the disadvantages: it operates in the eye-safe wavelength regime; it uses liquid oxygen as the gain medium and as the diode array coolant, resulting in the reduction or elimination of a separate thermal control system; it uses efficient, high power diode pump sources resulting in a compact device much smaller than either chemical or solid state lasers; and its pulse length is variable from continuous to sub-picosecond, allowing flexibility in weapons effects.

(U) Program Plans:

- Perform system/utility analyses.
- Develop and demonstrate a 1 kW output power laser design.
- Develop and demonstrate 20 kW laser design.
- Develop 100 kW-to-megawatt laser design.
- Develop kilowatt-class red diode stacks.
- Develop high-power mirror coatings for this wavelength.

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	FY 2005	FY 2006	FY 2007
Architecture for Diode High Energy Laser Systems	0.000	8.237	8.000

(U) This program will develop all-solid-state laser diode drivers with integrated fault mode protection that will decrease the size and weight of these laser systems by a factor of 4 (by allowing the laser diode array to operate at elevated temperature), increase the diode array lifetime tenfold, and decease lifecycle costs fivefold. These improvements will be attained for diode laser arrays operating in the IR, visible and ultra-violet regions of the spectrum. By allowing operation at higher temperatures, these new drivers will allow broader tuning of the laser light which is crucial to the detection of both chemical and biological agents with high signal-to-noise and low probability-of-false-alarm. These new diode laser drivers will utilize feedback control systems which detect electrical and optical filamentation within the laser diode and laser diode bars, and then interrupt power to the laser diode system before thermal instabilities can lead to accelerated diode aging and premature diode failure.

(U) Program Plans:

- Demonstrate a three-fold improvement in diode array lifetime with a preliminary data set that projects to tenfold improvements in diode lifetime.
- Integrate fault mode protection for stable operation of the laser diode array at elevated temperatures which leads to a fourfold reduction in the size and weight of the thermal cooling and heat exchanger systems which currently dominate laser size and weight.
- Combine new technologies being developed in industry and universities/government laboratories to provide the ultra-compact, tunable, solid-state lasers required for remote detection and destruction of both chemical and biological agents.

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	FY 2005	FY 2006	FY 2007
Photonic High Power Microwave System	0.000	1.000	2.000

(U) The goal of the Photonic High Power Microwave System program is to develop and demonstrate a highly compact high power microwave system capable of multiple waveforms and scaleable in power from the Gigawatt to Terawatt range. The enabling technology is the implementation of optically driven switches integrated directly into the radiating array structure. This technology will enable tactical air, land, and sea platforms to address directed energy missions ranging from electronic attack to anti-ship missile defeat.

(U) Program Plans:
- Conduct preliminary engineering studies.
- Perform initial concept development.

	FY 2005	FY 2006	FY 2007
Rapid Checkpoint Screening	5.010	4.466	3.740

(U) The Rapid Checkpoint Screening program will develop and demonstrate techniques and sensors to detect life-threatening deceptions in military controlled portals such as military checkpoints that are compatible with existing portal screen approaches.

(U) Program Plans:
- Identify physiological signals that correlate with deception including laser vibrometry, lidars, multi-spectral eye tracking, and short range electrical potential.
- Validate the measurement process.
- Establish new concepts for understanding deception processes on a scientific basis.

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	FY 2005	FY 2006	FY 2007
Efficient Mid-Wave Infrared Lasers (EMIL)	0.000	0.000	2.000

(U) The Efficient Mid-Wave Infrared Lasers (EMIL) program will develop efficient solid-state coherent sources to cover the atmospheric transmission bands in the mid-wave infrared (MWIR; 3-5 µm). Infrared countermeasure (IRCM) systems in particular depend on intense sources at these bands. The current generation IRCM systems utilize diode-pumped Tm lasers used to pump optical parametric oscillators (OPO), most commonly based on zinc germanium phosphide (ZGP).

(U) The lasers developed in this program will operate across the three relevant bands within the MWIR at 10W power with wallplug efficiencies of at least ten percent. By virtue of the enormous volumetric reduction (100-1000X), power reduction (10X), and superior pulse format (cw-operation), such sources will enable new architectures and approaches permitting IRCM systems to be deployed on platforms (e.g., rotocraft) which are highly vulnerable to Man Portable Air Defense Systems (MANPADS) and other threats but for which current IRCM systems are prohibitive or are inadequate (e.g., unable to defeat staring sensors). At least two diode-based laser approaches will be explored in this program, both involving antimonide-based compound semiconductor (ABCS) materials. These include intersubband-based quantum cascade lasers (QCLs) and type-II antimonide lasers, including so-called "W-configuration" approaches, the name taken from the shape of the conduction band profile.

(U) Program Plans:
- Design and deposition of complex multi-layered structures incorporating antimonides.
- Reduce internal losses across the large number of layers.
- Achieve the 10-W total output power by combining power of multiple devices.
- Overcome the parasitic mechanisms such as Auger recombination to reduce lasing threshold and achieve high temperature operation.

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	FY 2005	FY 2006	FY 2007
Sonic Projector	0.000	0.000	2.500

(U) The goal of the Sonic Projector program is to provide special forces with a method of surreptitious audio communication at distances over 1 km. Sonic Projector technology is based on the non-linear interaction of sound in air translating an ultrasonic signal into audible sound. The Sonic Projector will be designed to be a man-deployable system, using high power acoustic transducer technology and signal processing algorithms which result in no, or unintelligible, sound everywhere but at the intended target. The Sonic Projector system could be used for concealed communications in an urban environment with friendly or neutral subjects for hostage rescue.

(U) Program Plans:
- Complete initial feasibility studies.
- Create concept of operations and conduct military utility analyses.
- Develop and demonstrate initial prototype.

	FY 2005	FY 2006	FY 2007
Mission Specific Processing (MSP)	2.563	0.000	0.000

(U) The Mission Specific Processing (MSP) program extends technologies to support the design of highly optimized embedded processors that are required in the most severely constrained DoD applications. The technology developed by this 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 providing a ten-fold gain in power-performance over current standard cell Application Specific Integrated Circuits (ASIC) designs by incorporating full-custom design optimizations into standard libraries. The MSP design flow methodology will be made available to organizations such as the Defense Microelectronics Activity (DMEA) and the Air Force Research Lab (AFRL). The MSP advanced processor will be used in DoD system demonstrations and an additional MSP chip test bed and radar simulator will be transitioned to the AFRL to enable potential Air Force system insertion.

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(U) Program Plans:
- Developed detailed system architecture of wideband adaptive radar/electronic intelligence-/seeker receiver enabled by MSP method.
- Developed a wideband adaptive radar receiver based on MSP custom cell libraries and modules.
- Conducted simulation and benchmarking of initial custom design techniques in the context of mission specific signal processing requirements.
- Demonstrated a ten-fold performance improvement in custom radar signal processing chips.
- Completed library of key digital signal processing function kernels and supporting tool augmentations.
- Completed development and demonstration of space-time adaptive processor for seeker-receiver.
- Conducted first pass evaluation of semi-custom, full scale chip in a space-time adaptive receiver testbed.
- Demonstrated full scale ASIC development using MSP architectures and techniques focusing on MSP design methodologies that reduce design time requirements as compared with full custom.
- Completed a demonstration that addresses system level issues and quantifies the increased performance relative to standard cell ASIC designs.
- Fabricated the MSP designed ASIC under DoD's Trusted Foundry program.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Aeronautics Technology TT-07	47.876	58.290	78.027	84.462	100.452	105.752	80.752

(U) Mission Description:

(U) Aeronautics Technology efforts will address high payoff opportunities that dramatically reduce costs associated with advanced aeronautical systems and/or provide revolutionary new system capabilities for satisfying current and projected military mission requirements. This includes advanced technology studies of revolutionary propulsion and vehicle concepts; sophisticated fabrication methods and examination of novel materials for aeronautic system applications.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Micro Adaptive Flow Control (MAFC)	9.336	4.010	4.200

(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, microelectromechanical systems (MEMS)-based microactuators, pulsed-blowing, combustion actuators and smart structures to cause the delay, or prevention of fluid flow separation. MAFC technologies have been and will continue to be explored for applications such as download and drag reduction for air vehicles, facilitation of long-range flight with reduced fuel consumption and logistical implications using vortex mitigation, adaptive lift-on-demand for agile missiles and uninhabited tactical aircraft, supersonic boundary layer control, lightweight gas turbine engines, and low-drag, non-intrusive methods to aerodynamically steer projectiles for extended range and precision.

(U) Program Plans:
- Executed Phase II, high speed, closed loop technology demonstrations.
- Executed MAFC download reduction testing on the XV-15.
- Completed SCORPION closed loop system design and fabrication.

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- Completed SCORPION Phase III technology roadmap.
- Complete sled design and fabrication for High Frequency Excitation for Supersonic Weapons Release (HIFEX) phase III test.
- Complete HIFEX system design and fabrication for HIFEX phase III test.
- Complete SCORPION system design and fabrication for SCORPION phase III test.
- Designed and integrated SCORPION full-scale control system.
- Complete 4 Mach 2.0 HIFEX system sled tests.
- Configure and execute Phase III full-scale technology demonstrations.

	FY 2005	FY 2006	FY 2007
Miniature Propulsion Concepts (formerly Small Scale Propulsion Systems)	7.995	5.340	5.334

(U) Small UAV payload and endurance capabilities can be expanded by increasing the power density and efficiency of their power plants. This program will develop concepts for small scale class propulsion systems. Small gas turbine engines are typically very inefficient, below 7% for engines below 10 horsepower. This program will develop gas turbine engines under 10 horsepower with a power density greater than 2HP/pound and a thermal efficiency greater than 25%. In addition, novel concepts for developing micro UAV's that emulate and/or borrow propulsion approaches from birds will be developed. These will provide a unique Intelligence, Surveillance, and Reconnaissance (ISR) capability for the dismounted soldier.

(U) Program Plans:

- Demonstrate small, long endurance engine using novel designs for un-cooled ceramic components with power density greater than 2 HP/lb, efficiency greater than 25% and a durability of greater than 500 hours.
- Demonstrate a multifunctional wing structure plus battery for micro air vehicles (MAV) that yields three times more duration than a traditional wing structure and conventional battery.
- Investigate compatibility of optical flow and uncooled IR approaches with multifunctional structures to enhance surveillance capability.
- Transition micro air vehicles to military applications.

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	FY 2005	FY 2006	FY 2007
Peregrine / UAV Killer	1.410	3.050	5.146

(U) The Peregrine Unmanned Air Vehicle (UAV) Killer program will develop a small, low-cost, high-endurance UAV, with a high dash speed, capable of destroying most enemy UAVs. Small UAVs with GPS guidance systems have reached such a low cost level that expendable UAV programs are now emerging and GPS capable avionics are available for the hobby market. Current options to counter such a threat, especially at high altitude, involve expensive ground launched anti-air systems or the exposure of manned interceptor aircraft. The Peregrine program will develop and demonstrate a UAV interceptor aircraft that will utilize a dual propulsive power system to provide very high endurance for the loiter and surveillance period, and a very high dash speed for intercept and kill. The program will also identify operating scenarios and system requirements for the protection zone approach for both domestic situations and regions of conflict, and will develop a suitable system design and concept of operations.

(U) Program Plans:
- Define system requirements.
- Develop concept design.
- Demonstrate aircraft performance and kill capability.

	FY 2005	FY 2006	FY 2007
Walrus	8.140	0.000	0.000

(U) The Walrus program was established to develop, evaluate, and demonstrate a range of technologies to enable the development of a very large airlift concept capable of controlling lift in all stages of air or ground operations including off-loading of payload without taking onboard ballast other than air. Unlike earlier generation airships, it would have been a heavier-than-air vehicle, generating lift through a combination of technologies and approaches including aerodynamics, thrust vectoring and gas buoyancy generation. The program planned to develop an operational vehicle (OV) concept and to conduct risk reduction demonstrations by executing a technology development and assessment plan

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including a Walrus Advanced Technology Demonstration (ATD) aircraft. The ATD vehicle and other technology demonstrations (bench tests and flight tests on other vehicles) would have demonstrated scalable aircraft technology to enable the achievement of the Walrus program goals. The program's first phase funded system studies and development of a notional concept of the objective vehicle and identification of the critical demonstration technologies to reduce risk for the concept. The program will complete at the conclusion of Phase I.

(U) Program Plans:
- Define and develop a notional objective air vehicle concept having a payload capability circa 500 tons.
- Identify critical breakthrough technologies.
- Complete final report.

	FY 2005	FY 2006	FY 2007
High Speed / Hypersonic Reusable Demonstration	15.000	30.000	20.700

(U) This program is a joint DARPA/Air Force initiative that is designing, developing and demonstrating a combined cycle engine and reusable hypersonic cruiser in conjunction with the Falcon program (PE 0603287E, Project SPC-01). Ultimately, the studies and developments under this project may result in the first controllable, recoverable, and reusable hypersonic system demonstration. Initial designs will allow for either a manned or unmanned version, and provide viable options for long-range strike and affordable access to space. The program is divided into two efforts—the High Speed Turbine Engine Demonstration (HiSTED) and the Scramjet Engine Demonstration (SED).

(U) The HiSTED objectives are to design, fabricate, and ground test a high Mach expendable turbine engine capable of Mach 3-4+ operation. The objective of the ground demonstration is to verify, via simulated altitude testing, that engine performance and operability characteristics at key transonic and maximum Mach/altitude cruise flight conditions meet anticipated system application needs. Successful completion of the Phase I ground demonstration will enable Phase II development of a reusable turbine-based combined cycle engine capable of accelerating a hypersonic cruise vehicle to Mach 4+.

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(U) The SED effort seeks to design, fabricate, and fly a hypersonic vehicle powered by the HyTech scramjet engine over a broad range of Mach numbers. The SED flight vehicle will be boosted to Mach 4.5 where the scramjet engine will be started and the vehicle will accelerate to Mach 6.5 to Mach 7+. This will demonstrate a scramjet engine that produces thrust greater than vehicle drag, accelerating a free flight vehicle over a range of Mach numbers. This will be the first-ever demonstration of a flight-weight, fuel-cooled scramjet-powered vehicle. It will also establish the viability of the scramjet engine for integration with high speed turbines such as that developed under HiSTED and/or rocket engines to create combined cycle engines for hypersonic cruise vehicles and affordable on-demand access to space systems.

(U) Program Plans:

- HiSTED
  - Complete high temperature turbine components design and fabrication.
  - Assess supercritical fuels.
  - Assess high temperature lubrications and bearings.
  - Perform component integration.
  - Conduct integrated engine ground testing.

- SED
  - Develop flight vehicle design.
  - Conduct freejet engine testing.
  - Fabricate flight demo vehicle.
  - Conduct flight testing.

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	FY 2005	FY 2006	FY 2007
Helicopter Quieting	5.995	6.020	8.472

(U) Studies and analysis of military helicopter operations have shown that the survivability and lethality of U.S. helicopters can be increased by reducing their acoustic signature, which will make them more difficult to detect, track, and engage. The Helicopter Quieting Program is developing revolutionary new rotor blade design tools that will enable the creation of novel rotor blades that can dramatically reduce the acoustic signature of a helicopter without sacrificing flight performance. Current rotor blade development is conducted on a trial and error basis, relying on an iterative cycle of analysis and model wind tunnel tests (time consuming and costly) or going straight from analysis to full-scale wind tunnel/flight test (high risk and costly). Because of the significant issues of time, cost, and risk, helicopter rotor designers cannot explore the revolutionary potential of emerging new rotor noise-reducing technologies in the design process. This program will leverage recent advances in computational fluid dynamics to develop physics-based predictive design tools that will allow designers to develop revolutionary rotor blade designs with vastly improved acoustic characteristics. The predictive tools will be tested using existing data sets and data collected from fully instrumented full-scale and model-scale experiments. The tools will then be used to design new blades that yield a significant reduction in low-frequency in-plane signatures without impacting performance compared to a baseline design.

(U) Program Plans:

- Develop predictive blade design tools.
- Conduct a study to guide the development goals for new blade designs based on operational models.
- Validate models using experimental data.
- Use the tools to support the design of new blades that yield a significant reduction in low-frequency, in-plane signature.

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	FY 2005	FY 2006	FY 2007
Nano-Flapping Air Vehicles	0.000	2.300	6.956

(U) The goal of this program is to develop flapping air vehicle technology that results in a bio-inspired flapping air vehicle with less than two inch wingspan and gross takeoff weight of approximately ten grams or less. Operations in the urban terrain require sensors that can navigate in difficult terrain and be inserted without being detected. Small air vehicles capable of navigating interior domains without GPS would enable autonomous prosecution of a number of high risk missions that are currently performed by warfighters. Key enabling technologies include, flapping wing aerodynamics, kinematics and flight dynamics, lightweight aeroelastically tailored wing structures, miniature navigation systems, micro-propulsion systems and small payloads. This effort will also examine novel materials that can be used to develop integrated wing structures, which change composition to achieve multiple expressions. The program would result in the use of vehicles, which could be camouflaged, or blend into the surrounding landscape, enabling in-theater disposal and prevention of mission detection/compromise.

(U) Program Plans:

- Conduct detailed investigations on unsteady aerodynamic physics to understand fundamental aerodynamic issues.
- Conduct studies integrating aeroelastic phenomena to improve flapping performance.
- Conduct survey/studies of novel building materials.
- Design wing geometry and flapping mechanism for future integration into vehicle design.
- Conduct detailed flapping tests to refine aerodynamic wing-mechanism design.
- Integrate wing design with air vehicle.

	FY 2005	FY 2006	FY 2007
Flare Aero Structures	0.000	2.000	4.500

(U) The Flare Aero Structures program will explore and develop a new approach to take off and landing of fixed wing aircraft. The landing field requirement for fixed wing aircraft limit their use in both confined (e.g. urban) and remote unprepared areas. This program will explore

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unsteady aerodynamics during rapid pitch up or flare landing maneuvers. It is known that very high lift coefficients can be obtained for a short period of time during such a maneuver. The technical challenge is to develop the aero structures, control effectors and control logic that will allow for a practical application of this phenomenon to fixed wing aircraft to allow landing in a very short distance. This could lead to small/medium UAVs that can land on unprepared areas without the need for an arresting system. Additionally, an application of this technology for paratroops will be evaluated.

(U) Program Plans:
- Develop aerodynamic models and control logic.
- Conduct flight experiments with scaled aircraft.
- Correlate computer models with experimental data.
- Design and build prototype systems.

	FY 2005	FY 2006	FY 2007
Macaw	0.000	5.570	6.469

(U) The goal of the Macaw program is to develop a helicopter emulator system carried on a small UAV. The system would provide acoustic and thermal (infrared) emulation of a variety of helicopters. Macaw could be used for mine clearing/route determination as well as escort missions. The system would draw fire from ground based adversaries, and relay the information back to the operator for off-board location and prosecution. The Macaw system would protect Army and SOCOM helicopters from ground fire, small arms, rocket-propelled grenades (RPGs), man-portable air defense systems (MANPADS), and anti-helicopter mines.

(U) Program Plans:
- Model the acoustic and thermal (IR) signatures of common helicopters.
- Develop concepts to characterize common helicopter acoustic and thermal (IR) signatures.
- Select and integrate sensor and UAV.
- Conduct field tests to determine system capability against potential threats.

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	FY 2005	FY 2006	FY 2007
Distributed Embedded Propulsion	0.000	0.000	6.000

(U) The Distributed Embedded Propulsion project will explore fully integrated engine/wing designs to take maximum advantage of a fully coupled engine/wing system. It is expected that distribution propulsive flow over the wing surface would allow circulation control on the wing through both suction and tangential blowing. Circulation control on the wing provided by the embedded distributed propulsion systems would provide unprecedented maximum lift coefficients, with associated reduction in takeoff and landing distance. Military transition targets would be short takeoff and landing airlift and transport vehicles, benefiting from improvements possible in takeoff and landing distance, as well as innovative concepts such as high aspect ratio flying wings. The program will conduct a series of design, sizing and demonstration efforts, culminating in either a wind tunnel or flight test of a circulation control wing using distributed propulsion, and/or a ground or flight test of a distributed embedded propulsion system.

(U) Program Plans:
- Conduct trade studies on aircraft sizing.
- Evaluate conceptual designs of distributed embedded propulsion concepts.
- Determine engine requirements for distributed propulsion system.
- Initiate design of distributed embedded propulsion experiments.

	FY 2005	FY 2006	FY 2007
Laminar Flow Flight Demonstration	0.000	0.000	4.200

(U) The Laminar Flow Flight Demonstration effort will explore the development of an extended laminar flow wing at both subsonic and supersonic operating conditions, with the potential for a drag reduction of up to 25% compared to a typical fully turbulent wing. Crossflow instabilities dominate the transition process for swept wings. Recent advances in theoretical understanding of the crossflow receptivity and transition process have led to innovative, passive control concepts for the crossflow transition process. Test facilities are not available to

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demonstrate this flight concept in a quiet flow environment at Reynolds numbers and Mach numbers. Flight testing a swept wing laminar flow control concept appears to be the most direct route to validation of this technology, enabling future aircraft designs to adopt passive crossflow control devices as a proven technology.

(U) Program Plans:
- Conduct feasibility study of high Reynolds number flight test.
- Initiate design of flight test experiment.
- Initiate design of laminar flow wing for demonstration.

	FY 2005	FY 2006	FY 2007
Long Endurance Autonomous Powered Powerfoil (LEAPP)	0.000	0.000	1.500

(U) The goal of the Long Endurance Autonomous Powered Powerfoil (LEAPP) program is to design, develop, integrate and demonstrate the enabling technologies and system capabilities required to perform precision airdrop for payloads of approximately 200 lbs over long range. The enabling technologies are precision guidance, autonomous operations, and parafoil aerodynamic performance. A LEAPP system will provide Special Forces with an order of magnitude improvement in precision airdrop along with a 100 percent improvement in range and endurance. In addition, the LEAPP will have flexibility to be deployed rapidly and will be affordable based on modular system design and construction.

(U) Program Plans:
- Develop LEAPP preliminary design, risk management plan, and technology and system maturation plan.
- Conduct system trades, effectiveness, and affordability through modeling and simulation and perform system level tests for specific missions.

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	FY 2005	FY 2006	FY 2007
Propulsive Anti-Torque System (PATS)	0.000	0.000	2.550

(U) The goal of the Propulsive Anti-Torque System (PATS) program is to design, develop, integrate and demonstrate a novel propulsive anti-torque system that significantly increases the performance and survivability of rotorcraft. PATS will enable more efficient use of engine horsepower and transmission capabilities providing increased speed, a significant decrease in signatures, and elimination of the tail rotor. PATS will be demonstrated on the United States Marine Corps AH-1Z Super Cobra attack helicopter utilizing the existing AH-1Z engines, transmission, and airframe.

(U) Program Plans:
- Design and fabricate the AH-1Z PATS ground test demonstrator.
- Complete ground demonstrations.
- Validate PATS controls and obtain air worthiness release.
- Conduct flight test demonstrations and validate performance estimates.

	FY 2005	FY 2006	FY 2007
Tethered Urban Airborne Node (TETURAN)	0.000	0.000	2.000

(U) The goal of the Tethered Urban Airborne Node (TETURAN) program is to design, develop, integrate and demonstrate the enabling technologies and system capabilities required to develop a combat vehicle launched tethered ducted fan UAV which can operate in the vertical confines and canyons of the urban environment. The purpose of the vehicle is to carry three specific types of elevated payloads: communications relay and router nodes, GPS pseudolites, and imaging sensor payloads. The purpose of the program is to three-fold: (1) design, develop, build and test the airframe, (2) design, develop, integrate and test the GPS pseudolites, and (3) to integrate and test state of the art communications nodes and imaging sensors. Technical foci of the program include high power photovoltaics enabled by tethered laser illumination, in hub ring electric motors for ducted fan propulsion, multiwavelength fiber tethers for simultaneous data and power transmission use, and GPS pseudolite

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miniaturization. Payload mass fraction for TETURAN should be high and it is expected that a modular payload of five pounds should be reasonable to achieve.

(U) Program Plans:
- Conduct preliminary system design.
- Design, develop and build tethered ducted fan airframe and control system.
- Design, develop and test ring based fan electric motors.
- Develop and test dual mode fibers – power transmission and data comms.
- Validate photovoltaics for on board power generation.
- Conduct military experimentation to validate CONOPS.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Network Centric Enabling Technology TT-13	56.341	66.761	81.151	117.259	121.328	126.458	111.258

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

(U) This project provides technology to build mission applications explicitly tailored to exploit the features of network-centric system architectures. Mission applications include signal processing, detection, tracking, identification, situation understanding, planning, and control functions. These applications will integrate: (1) external sensors and processors that provide data on targets and mission contexts; (2) external platforms, both air and surface, that deliver sensors and munitions to designated areas; (3) intelligence processing systems at all levels of command; and (4) external communications networks that provide connectivity between computing nodes located on the platforms, at field command centers, and headquarters. The mission applications share data to form consistent battlespace understanding tailored to the needs of commanders at each node. The types of tailoring include common operational pictures, timelines, and resource usage descriptions. The mission applications also negotiate plans for future operations based on mission needs presented at each node. To maintain focus on operationally relevant problems, the project's technical goals are posed and evaluated in the context of mixed manned/unmanned forces.

(U) Technologies developed in this project enable localized and distributed collaborative processing. This allows networks of sensors to rapidly adapt to changing force mixes, communications connectivity, and mission objectives. The technology developed permits the distributed command and intelligence systems to effectively collaborate in a dynamic environment. Technologies are demonstrated and evaluated in the laboratory and in hardware-in-the-loop demonstrations. Demonstrations employ both stationary and autonomous mobile platforms. Operational benefits are: (1) smaller forward deployment of image and signal analysts in complex operating conditions including urban battlefields; (2) deeper understanding of the evolving stability and support operational environment; (3) consistent integration of target and environment information; and (4) flexible operational tactics and procedures to find evasive targets in difficult environments.

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(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Networked Embedded Systems Technology (NEST)	9.255	6.000	6.000

(U) The Networked Embedded Systems Technology (NEST) program provides robust coordination and synthesis services for sensor network systems. NEST is the key software building block needed to enable ad-hoc or structured wireless sensor networks to function together. Applications of these systems include: localization of snipers by collaborative sensor fusion in real time (i.e., within two seconds), sensor network-based tripwires and chokepoints for detection and discrimination of personnel and vehicles, and wide-area, 24/7 surveillance of long linear structures, (i.e., pipelines and borders). These applications require from tens to tens of thousands of nodes. NEST produces reusable software libraries and design tools that simplify the development of wireless sensor network applications. NEST is planned for transition to the U.S. Special Operations Command, U.S. Southern Command, and the U.S. Army.

(U) In particular, this technology is being combined with an active exciter to develop a radar-like sensor system to measure human activity inside buildings. The approach exploits existing wiring networks (power) to provide persistent surveillance of buildings and below grade areas. The concept is to insert radar pulses into a building's main power feed and read pulse returns from a wireless network of sensors placed around the building. The building's own wiring network serves as a transmission line to conduct these pulses throughout a structure, and every outlet or switch serves as an antenna to couple these radar waves to and from free-space.

(U) Program Plans:
- Designed deterministic and probabilistic methods for self-stabilizing protocols for lightweight coordination services, such as global clock synchronization and/or sensor localization.
- Developed design tools for the customization of coordination-services to specific applications based on requirements and platform characteristics.
- Developed formal modeling and verification techniques for coordination and integration.

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- Develop tools for the automatic composition and verification of application-specific coordination service packages; demonstrate the utility of these tools in a fully integrated system consisting of a large network of heterogeneous sensors.
- Develop tools for remotely reprogramming large scale sensor networks and services for authentication and data encryption in those networks.
- Develop and populate a repository of customizable/adaptable services for real-time coordination and synthesis that support military applications.
- Develop prototype pulsing and sensing system to measure phenomenology, insertion losses, and radiation efficiency.
- Demonstrate, in non-real time experiments, target localization and tracking in a realistic multi-story urban structure.
- Conduct final field experiments and Military Utility Assessments.

	FY 2005	FY 2006	FY 2007
Combat Zones That See (CZTS)	8.213	7.436	5.000

(U) The Combat Zones That See (CZTS) project will improve the situational awareness, effectiveness and force protection of U.S. military forces in foreign urban environments (e.g., Baghdad). CZTS will provide close-in sensing and extended reconnaissance capabilities using a network of video sensors. The system will track vehicles over wide urban areas using sparse arrays of video cameras and automatically detect vehicles that may be involved in hostile activities based on the observed tracks. This network will produce an extreme amount of data for human analysis, so advanced video understanding algorithms embedded in commercial-off-the-shelf hardware systems will monitor video feeds automatically. Reconnaissance, intelligence, and targeting information needed to provide close-in, 24/7 support for military operations in urban terrain (MOUT) will then be generated. CZTS will enable vehicle identification with a 10,000-fold reduction in the bandwidth required to transmit key data across the camera network and will provide the capability to track vehicles non-continuously across extended distances. The CZTS goal is to demonstrate technology packaged into a flexible ground-deployed system.

(U) Program Plans:

- Develop, install overseas, and evaluate a force protection prototype that employs approximately 30 cameras.
- Demonstrate sustained tracking of individual vehicles using sensors whose fields-of-view do not overlap.

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- Use vehicle track data to calibrate cameras, learn patterns of activity, and retrieve similar or related events from a track database.
- Employ motion-pattern analysis to assist in finding common elements among collected tracks.
- Develop techniques to optimize the location and orientation for emplacing cameras.
- Develop methodologies for the efficient and timely management of the video network.
- Develop, install, and evaluate a rapid deployment prototype using approximately 100 rapidly deployed cameras.

	FY 2005	FY 2006	FY 2007
Automated Battle Management	12.800	13.723	20.400

(U) The pace of battle will continue to increase as capable platforms and effective communication networks become operational. While experienced commanders are required to formulate strategy and select tactics, the increased operational tempo will demand more automation of low-level decision processes, such as route-finding, weapon/target pairing, and sensor scheduling. Some elements of these processes, such as collision avoidance and navigation, will be embedded in each platform. However, groups of platforms will be able to execute cooperative tactics to achieve coordinated effects. This cross-platform coordination and synchronization requires new technologies that can carry out aggregate maneuvers and tasks, while leveraging the functions embedded in each platform. This program is developing novel technologies for multi-platform, automated battle management at the tactical level, in the air, on the ground, and within mobile sensor networks.

- The Collaborative Networked Autonomous Vehicles (CNAV) (formerly Mission Driven Control of Autonomous Robotic Systems) program will develop autonomous control methods to cause distributed platforms (Unmanned Undersea Vehicles - UUVs) to self-organize and distribute tasks through judicious transactions conveyed over a shared communications network. The CNAV Program will illustrate these capabilities through development of a capability for submerged target Intelligence, Surveillance, and Reconnaissance (ISR) in restrictive littoral waters. CNAV will provide this capability by creating a field of dozens or hundreds of UUVs, networked through Low Probability of Interception/Low Probability of Detection (LPI/LPD) acoustic wireless communications and working collaboratively and autonomously to detect, classify, localize and track target submarines transiting the field. The field will be self-organizing and self-healing and will have the capability to close on submerged targets. The CNAV field will also be self-re-organizing, adapting to changes in environmental and operational conditions. A reach-back capability will allow reporting of field health and will enable high-level orders

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and control functions to be provided to the field. CNAV will also result in a significant reduction in the cost per square mile for submerged target ISR in the littoral domain.

- The Organic Sensor Exploitation Network (OSEN) program will develop rapid, highly autonomous techniques for sensor exploitation by leveraging technology from the NEST program to support autonomous sensor networks in ground warfare. The goal of OSEN is to provide network-enabling technology for processes currently performed at centralized ground stations and analysis centers. The objective is to move processing closer to the sensor to reduce the need for expensive communications back to a central site and provide robustness to unexpected loss of platforms, communications disruptions, and unpredictable target behavior. OSEN is developing technology to: (1) permit on-board exploitation of sensor data from remotely deployed sensor nodes; (2) support correlation of information developed across different platforms; (3) detect, track, and identify targets in the field-of-view of a platform; (4) cue other sensors to acquire a target; and (5) transition targets to other platforms as different targets move through sensor fields-of-view. OSEN system studies will evaluate the relative value of different sensor mixes against low-flying aircraft, ground vehicles, dismounted infantry, and irregular forces. Sensor candidates include: electro-optical, infrared, radar, passive RF, acoustic, seismic, and magnetics which may be fixed or mounted on mobile platforms. The program accommodates variable communications connectivity; models predict changes caused by line-of-sight occlusions.

(U) Program Plans:

– Collaborative Networked Autonomous Vehicles (CNAV)
  - -- Develop secure, robust underwater wireless communications and networking.
  - -- Perform intelligent routing of threat characteristic and track data through the field to alert CNAV nodes down stream to position or reposition for target pursuit and intercept.
  - -- Demonstrate fully autonomous and collaborative CNAV field deployment, autonomous field set-up and self-localization, distributed common tactical operational picture, self-healing and reconfiguration, and threat pursuit and interception.
  - -- Demonstrate collaborative automated target detection, classification, localization and tracking (DCLT).

– Organic Sensor Exploitation Networks (OSEN)
  - -- Define representative sensor mixes and operational scenarios.
  - -- Perform analytical trade studies to generate representative sensor network components and tactics.

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-- Develop a network node architecture adaptable to the devices present at that node.
-- Prototype candidate algorithms for each function (search, detect, track, identify, correlation, hand off) based on alternative technologies.
-- Evaluate candidate algorithms in a synthetic environment to calibrate and verify performance models.
-- Insert selected algorithms into a hardware-in-the-loop testbed; demonstrate practical utility and verify system performance.

	FY 2005	FY 2006	FY 2007
Urban Warfare Robotic Surveillance (URS)	3.554	4.605	7.444

(U) The Urban Warfare Robotic Surveillance System (URS) program will develop new mobile sensor systems, carried on both long-endurance ground and short-endurance air platforms, to support warfighter operations in constrained urban environments. URS is exploring a mix of sensor technologies (Electro-Optical/ Infrared video, active optics, radar, acoustic, magnetic, chemical, and RF direction finding). Sensors are being tested in environments characterized by complex multi-path propagation, limited lines-of-sight, and frequent obscuration. Platforms and sensor networks will be designed to operate in urban exterior, underground, and indoor environments. Communications repeaters and routers will be included for terrestrial connectivity to all platforms that also provide for autonomous operation if communications are interrupted. The program includes means to resupply fuel and power to forward-deployed platforms. A program demonstration will deliver a prototype robotic squad that will provide integrated urban surveillance to augment or replace dismounted infantry in dangerous operations. URS missions include route clearing, flank protection, tunnel clearing, and scout and peacekeeping operations in urban environments.

(U) Program Plans:
– Select a baseline set of sensors, data links, and platforms.
– Design a flexible physical and logical architecture for a baseline URS system.
– Derive tasks and functions from standard urban reconnaissance operations plans.
– Construct a software testbed where candidate system components can be exercised in a synthetic urban battlespace.
– Develop alternative sensor models and algorithms (signal processing, object detection, object recognition, mapping, correlation, tracking, and route generation and communications management).

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– Compare alternatives in the synthetic testbed. Select combinations that offer the most robust and effective performance.
– Build a hardware testbed incorporating selected component sensors and algorithms.
– Exercise test platforms in a series of increasingly difficult mission/environment combinations.
– Improve sensors or algorithms that limit performance.

	FY 2005	FY 2006	FY 2007
Home Field	10.500	12.652	15.200

(U) The Home Field program will develop networked video and Laser Detection and Ranging (LADAR) processing technology that rapidly and reliably updates a 3D model of an urban area. It will provide 3D situational awareness with sufficient detail and accuracy to remove the "home field advantage" enjoyed by opponents. Detailed mobility maps to support ground vehicle routing will be inferred and generated, and detailed visibility data to support sensor positioning will then be derived to maximize coverage and minimize detectability. High fidelity baselines will be created to support change detection to cue searches for targets and anticipate changes due to current or impending meteorological events. The program will supply real-time context information to sensor managers, maneuver controllers, weapons operators, and commanders. Furthermore, the program will filter natural change from artificial change indicative of human (threat) activity and permit operation of military forces in hostile terrain normally deemed favorable to opponents because of their historical familiarity with hide points, sight lines, and mobility characteristics.

(U) A key part of Home Field is the development of large format re-writable holographic displays for urban terrain. Initially a 1' x 1' rewritable display will involve the adaptation and engineering of organic photorefractive polymer for a hogel-based display prototype. Home Field will conduct investigations in preparation for specification generation, to include alternative methods to coat very large substrates, illumination and light source alternatives like emitter matrix that can be scaled, and issues critical to parallel writing, such as intensity balancing, interleaving, and mechanical packing. This effort will culminate in the world's first full-motion hologram.

(U) Program Plans:
– Demonstrate a 3D-model method that uses distributed video and LADAR cameras in a mixed urban environment.
– Demonstrate the ability to extract architectural features, such as windows and doors, from close-in imagery.

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- Demonstrate an effective man-machine interface to edit/update the extracted features.
- Demonstrate a model update approach that keeps the urban cartographic representation current.
- Demonstrate rewritable holograms, large format (6' x 6') holograms, and a video-rate hologram.

	FY 2005	FY 2006	FY 2007
Adaptive Reflective Middleware Systems (ARMS)	5.800	6.120	8.860

(U) The Adaptive and Reflective Middleware Systems (ARMS) program is developing an integrated open system computing and information architecture. The initial focus is on the Total Ship Computing Environment (TSCE) in the DD(X) Future Surface Combatant Family of Ships; however, the technology is applicable to other network-centric DoD systems. The TSCE executes all tasks and mission applications optimized at the platform level, rather than the subsystem level. Autonomous TSCE systems require middleware and frameworks that adapt robustly to changes in environmental conditions. ARMS middleware coordinates the exchange of information predictably, scalably, dependably, and securely among shipboard entities by employing advanced Quality of Service (QoS) capabilities of the underlying network and end systems.

(U) Program Plans:

- Define and prototype algorithms, adaptive protocols, patterns, and technologies.
- Develop technologies to enable the use of the Java programming language in time-critical applications.
- Enforce security policies to enhance and support secure resource allocation, scheduling, and control; ensure stability and dependability across the network-centric TSCE.
- Develop robust meta-programming policies and mechanisms based on standards-based middleware.
- Define and prototype reflective techniques for synthesizing optimized distributed, real-time, and embedded middleware.
- Develop required information models, algorithms, and technologies; develop technologies to configure customizable, standards-compliant TSCE middleware and applications.
- Develop robust adaptive protocols, algorithms, patterns, and technologies that exploit standards-compliant middleware.

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- Develop and capture design expertise in information models. Formalize the successful techniques and constraints associated with building, generating, and validating QoS-enabled, middleware frameworks and protocol/service components for the DD(X) TSCE baselines.
- Demonstrate mature, standards-based middleware technologies for transition to the DD(X) Surface Combatant Family of Ships.

	FY 2005	FY 2006	FY 2007
Pre-Conflict Anticipation and Shaping (PCAS)	0.000	5.825	6.247

(U) The Pre-Conflict Anticipation and Shaping (PCAS) program develops and integrates a range of technologies into a unified system for supporting Theater Security Cooperation (TSC). PCAS technologies include quantitative and computational social science modeling and simulation, scenario generation, ontological modeling of security problems, advanced interactive visualization techniques, and agent-based programming. When integrated, these technologies and models allow combatant commanders and senior decision makers to understand and anticipate the societal/regional indicators that precipitate instability and conflict within an area of responsibility in time intervals ranging from six months to five years, then mitigate the impact of that instability by recommending shaping actions (military, Non Government Organizations (NGO), State, U.S. Agency for International Development (USAID), private companies) that address the causal factors of the instability. PCAS will help Combatant Command (COCOM) staffs identify unintended consequences of actions taken to influence or remediate situations and assist in the assessment of secondary/tertiary effects of actions, possibly delayed weeks, months, or years in time, that could have positive or negative effects on U.S. goals and objectives within countries and regions. The PCAS system will be tested and validated against current state-of-the-art practices, such as intelligence analysis reports that provide counsel about an area of operations using idiosyncratic mental models and research from open source and classified materials.

(U) Program Plans:

- Augment the suite of social science models with emerging computational social science model and theories that can be applied to assess and predict social change.
- Select a representative set of countries and regions in Pacific Command (PACOM) which are expected to range from stable to highly unstable social dynamics.
- Obtain and organize a large corpus of data describing the selected countries and regions that is useful to the models.

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- Build tools to automatically translate the data corpus into a form usable by the suite of quantitative and computational social science models.
- Build prototypes of software tools based on the identified social science theories and methodologies.
- Conduct regular experiments comparing predictions of the identified techniques with real-world events in an operational environment.
- Make rugged and operational the remaining techniques to form tools that can be transitioned to the staff at Combatant Commands (PACOM HQ).
- Demonstrated utility of models based on system dynamics, scaling laws, agent-based modeling, parametric search, and differential regressive equations to assess stability of two countries.

	FY 2005	FY 2006	FY 2007
Diagnostic Network Economies	0.000	6.000	6.000

(U) The Diagnostic Network Economies Program will obtain orders of magnitude improvement in the speed, accuracy, and efficiency of fault diagnosis in distributed systems that provide support for crucial network centric military operations, such as transmitting a common operational picture and maintaining information dominance. As network centric warfare systems are introduced, the management systems that are needed to operate these networks must become exceptionally robust. The Diagnostic Network Economies program will substantially reduce the risks associated with network-centric operations, and at the same time assure the agility of U. S. forces by developing effective network fault diagnosis capabilities that minimize the logistical footprint associated with that aspect of network management and reduce the opportunities for human error in the process.

(U) Program Plans:
- Develop techniques for optimizing the overhead of information collection in limited-bandwidth environments.
- Improve current capabilities to share diagnostic information appropriately and securely across multilevel security boundaries.
- Leverage and extend the available techniques for information fusion across multiple data sources, and anomaly detection.
- Distribute diagnostic capabilities without centralized points of failure.
- Explore new approaches to reasoning in the presence of partial and unreliable information.

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– Employ new approaches to discover and maintain dependencies within network centric warfare systems.

	FY 2005	FY 2006	FY 2007
Total Operating Picture Visualization and Understanding (TOPV&U)	0.000	0.000	6.000

(U) Effective operations require that Commanders have a decisive understanding of the operational environment. Effects-based Operations and the advent of asymmetric warfare have increased the amount, complexity, and scope of the information required to achieve that understanding. The Total Operating Picture Visualization and Understanding (TOPV&U) program will develop technologies for managing the complex streams of information describing modern conflicts. It will develop new technologies to: catalog, correlate and fuse these new forms of information into patterns; detect the presence of inaccuracy, inconsistency, incompleteness, uncertainty, ambiguity, and deception; and construct graphical and audio portrayals of the information to change human cognition and enable the commander to achieve a deeper and more complete understanding of the situation with a minimum of cognitive involvement. These technologies will enable commanders to gain a shared visualization and understanding (not just an awareness) of the total situation; not only the military situation but also the diplomatic, political, economic, social, information distribution and infrastructure situations as they affect military operations. The transition point and partner will be the Joint Forces Command. The program will include experimentation using live information feeds to determine the utility of the technologies when employed by experienced analysts and commanders.

(U) Program Plans:

– Develop new fusion technologies to correlate and fuse non-traditional forms of information into patterns.
– Detect the presence of inaccuracy, inconsistency, incompleteness, uncertainty, ambiguity, and deception.
– Develop and demonstrate the use of non-physics-based models of an adversarial coalition’s various political, social, economic, information dissemination and service infrastructure systems as well as its military or insurgent capabilities, as a means to organize, associate and correlate data points, and to forecast future activity.
– Develop and demonstrate graphical and audio transformations that generate portrayals of complex, multi-dimensional information which can exploit the potency of human cognition and enable the commander to achieve a deeper and more complete understanding of the situation with a minimum of cognitive involvement.

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	FY 2005	FY 2006	FY 2007
Eyes-On System	3.669	0.000	0.000

(U) The Eyes-On (EyO) System program developed multifunctional information gathering capability for an air launched micro-Unmanned Air Vehicle (micro-UAV). EyO employs very high-resolution, commercial off-the-shelf, electro-optical/infrared sensors integrated into a low-signature sensing platform. Commanders can employ the system to achieve visual human-in-the-loop confirmation of targets by going close-in and under-weather. Presurveying the engagement zone for collateral damage avoidance will support go/no-go attack decisions under restrictive rules of engagement. A limited loitering capability allows Eyes-On to support real-time bomb damage assessment following an attack. EyO utilizes line-of-sight RF communications and local command and control system technologies to deliver exquisite just-in-time visual confirmation to the warfighter. The program has developed the capability to support discrimination between non-combatants and combatants. As a forward-deployed, loitering, micro-robotic forward area controller, EyO could support long range weapon delivery by monitoring the target area throughout the weapon flyout. EyO adapted existing sensor and platform designs and fabricated prototype small UAVs in prototype quantities. Each prototype consists of the air vehicle, a sensor package, flight control system, and data link to the launch platform.

(U) Program Plans:
- Defined system architecture to include command and control requirements.
- Analyzed tradeoffs between sensing performance, target location and referencing designs, data rates, and smart processing aboard the small UAV.
- Developed candidate designs at different points on these trade-off curves.
- Simulated each design over a suite of missions and selected the design that provided the best overall actionable-ID capability.
- Installed the brassboard and selected sensor, signal processing, flight control and data link software on a recoverable test platform.
- Constructed and tested entire prototype systems.

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	FY 2005	FY 2006	FY 2007
Enhancement of Communications and Telemetry Support	0.000	1.700	0.000

(U) Select and fund initiatives for the enhancement of communications and telemetry support.

	FY 2005	FY 2006	FY 2007
MESH-Enabled Architecture	0.000	1.000	0.000

(U) Select and fund initiatives for MESH-enabled architecture.

	FY 2005	FY 2006	FY 2007
R31 Systems: Next Generation of Intelligent Comm.	0.000	1.700	0.000

(U) Select and fund initiatives for the next generation of intelligent communications.

	FY 2005	FY 2006	FY 2007
NASEC Through Wall Radar Imaging	2.550	0.000	0.000

(U) Continued work at the National Applied Software Engineering Center (NASEC) to design, build and utilize an experimental radar to support advances in thru-wall sensing at radio frequencies.

(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 Materials & Biological Technology PE 0602715E			
COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	252.168	288.753	297.277	308.261	315.107	316.107	273.107
Materials Processing Technology MBT-01	140.907	178.355	165.052	177.750	184.772	185.772	167.772
Biologically Based Materials and Devices MBT-02	111.261	110.398	132.225	130.511	130.335	130.335	105.335

(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 and biological systems that make possible a wide range of new military capabilities.

(U) The major goal of the Materials Processing Technology 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. Included in this project are efforts across a wide range of materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling for improvements in logistics (i.e., novel power sources, water purification, etc.).

(U) The Biologically Based Materials and Devices Project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials and devices as well as the commensurate influence of materials, physics and chemistry on new approaches to biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials to maintain performance, the use of biology's unique fabrication capabilities to produce structures that cannot be made any other way, the application of magnetic materials in biological applications, and the development of manufacturing tools that use biological components and processes for material synthesis.

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

	FY 2005	FY 2006	FY 2007
Previous President's Budget	256.480	294.188	299.844
Current Budget	252.168	288.753	297.277
Total Adjustments	-4.312	-5.435	-2.567
Congressional program reductions	-0.197	-10.185	
Congressional increases	0.000	4.750	
Reprogrammings	2.450		
SBIR/STTR transfer	-6.565		

(U) Change Summary Explanation:

FY 2005	The decrease reflects the SBIR/STTR transfer, the DOE transfer directed by P.L. 108-447 offset by an increase to realign the congressional add for Gelled Fuels and Oxidizers from OSD to DARPA for proper execution.
FY 2006	The decrease reflects a congressional cut to Bio-Magnetic Interfacing Concepts, undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission. These were offset by congressional adds to Nanotechnology Solutions, 3-D Microstructures and Strategic Materials.
FY 2007	Decrease reflects minor shift in program pricing and phasing.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Materials Processing Technology MBT-01	140.907	178.355	165.052	177.750	184.772	185.772	167.772

(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. Included in this project are efforts across a wide range of materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling improvements in logistics.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Structural Materials and Devices	35.319	49.000	51.020

(U) The Structural Materials and Devices program is exploiting emerging material science concepts and processing approaches to tailor the properties and performance of structural materials and devices to DoD requirements. Thrusts in this area include new concepts for ultra lightweight materials, amorphous and multi-functional materials for lowering the weight and increasing the performance of aircraft, ground vehicles, blast/ballistic protection and spacecraft structures. Approaches are also being developed for reducing the risk of introducing 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. New, low cost processing and fabrication techniques are also being developed to enable expanded use of new materials and structures in Defense applications as well as to produce novel materials that cannot be made through conventional processing approaches.

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(U) Program Plans:

- Develop multifunctional materials concepts designed to provide significant improvement in the capabilities of Defense systems by providing additional functions (e.g., self-healing, thermal control, blast protection, and power) to load bearing structures, quantify their performance and fabricate specific prototype systems.
- Develop a low cost, protective system based on novel material structures and topology to protect troops and trucks against ballistic threats, shrapnel and blasts from improvised explosive devices.
- Develop and verify models that predict bulk amorphous metal formation and behavior; use these models to produce amorphous materials and coatings with superior properties (including increased fracture toughness and high strain rate behavior and long-term corrosion resistance in saline environment) over crystalline material.
- Demonstrate structural materials fabrication (forming, joining, etc.) technologies that yield bulk amorphous metals suitable for Defense applications, including composites for space applications with 25% reduction in weight and 50% increase in specific properties and aluminum based amorphous alloys for turbine blade applications.
- Demonstrate and validate mathematical models and other critical technical issues for the accelerated insertion of materials that will allow designers to cut the insertion time of new materials by over 50 percent using materials of high value to DoD (turbine metals, aircraft structures).
- Explore techniques for large volume, low cost synthesis and assembly of nanomaterials and nanotubes with controlled attributes that are suitable for high toughness fibers and reinforcements; demonstrate these reinforcement concepts in structural composites in Defense applications such as advanced blast and ballistic damage tolerance.
- Develop models, mathematical techniques and novel sensors that when integrated with sensor data will capture the physics of failure and behavior prediction in materials suitable for assessing in-situ damage accumulation and will also provide current state awareness and structural performance prediction for Defense systems.
- Demonstrate the use of flight information to predict life and failure of critical structural components.
- Establish and demonstrate up to 20% performance improvements and engine durability of high performance gas turbine engines based on vaporization cooling.
- Demonstrate novel, cost effective processing routes for aerospace grade (low oxygen) titanium metal and alloys. Explore processing routes for other structural materials of interest to Defense.
- Demonstrate novel and reproducible process routes for directed, localized and controlled microstructure modification to achieve substantial improvements in structural material properties of interest to Defense, including bronze castings for Navy applications.
- Develop unique, three dimensional approaches for making and replicating materials and structures of interest to DoD.

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– Develop and demonstrate manufacturing technologies that can lead to significant reduction in DoD system cost, especially for low volume.

	FY 2005	FY 2006	FY 2007
Smart Materials and Actuators	28.000	38.000	38.000

(U) In this thrust, 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. “Intrinsically smart” materials that provide self-diagnosis and/or self-repair will be developed as well. Machines are being developed that will increase the individual soldier’s physical capabilities by augmenting speed, strength, and endurance. New combinations of advanced materials, devices, and structural architectures are being developed to allow military platforms to morph or change shape to adapt optimally to changing mission requirements and unpredictable environments. New materials and devices will enable the military to function more effectively in the urban theater of operations.

(U) Program Plans:

– Design, demonstrate and validate an integrated, untethered, and self-powered exoskeleton system for augmenting the locomotion and strength of soldiers. The interface of the machine and human will be dramatically enhanced by the development of novel sensor architectures and control algorithms.
– Demonstrate capabilities of the exoskeleton against specific military metrics and transfer to the Army.
– Develop and demonstrate novel fluidic and mechanical devices, and their associated driving electronics that exploit smart material transducers in order to create new high power actuators for a variety of military applications.
– Develop, design and test the actuators, materials, and control architectures necessary for achieving precise shape change in an airframe to demonstrate the advantages and enable capabilities afforded by the ability to change shape (morphing).
– Demonstrate capabilities of morphing aircraft technology in a wind tunnel.
– Develop and demonstrate key smart materials technologies for plasma fueled and turbulence harvesting aircraft. Develop ultra-light high temperature capability for hypersonic vehicles using novel approaches to enable reduced thermal load, boundary layer control and virtual shape control.
– Develop a rapidly deployable and reversible, portable lightweight barrier to control enemy mobility in urban areas such as intersections, alleyways, doorways, etc.

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– Develop new materials that will intelligently adapt properties (e.g., modulus, strength) in response to the environment.

	FY 2005	FY 2006	FY 2007
Functional Materials and Devices	25.000	38.605	25.000

(U) In this program, new materials and concepts are being applied to the development of functional materials and devices. A fundamental principle of this thrust is to design material microstructures at the scale appropriate to exploit fundamental interactions with the environment in order to create materials with unique properties. Among the materials being developed in this thrust are new permanent magnetic materials with significantly higher magnetic strength and higher operating temperature for motors, generators, flywheels, bearings and actuators. Unique multifunctional fibers that can be woven into fabrics are being developed. Engineered materials (metamaterials) are being developed that provide dramatically new electromagnetic behavior across the complete array of Defense applications. Also, the concept of pushing nanostructured materials into optical regimes to slow light and producing negative index materials promise to yield important new materials and devices for DoD.

(U) Program Plans:

– Develop and demonstrate novel magnetic meta-materials for DoD motor applications including: 1) high temperature, high strength soft magnetic materials for rotor and stator applications in turbine environments; and 2) permanent magnets with superior energy products.
– Develop and demonstrate novel microwave meta-materials that will enable novel antenna and radar designs with reduced size and improved bandwidth and efficiency.
– Develop and demonstrate novel materials that can be remotely switched between two stable electromagnetic and/or structural configurations, including munitions with controllable sensitivity.
– Extend the frequency of operation and/or operational bandwidth of “negative index” or “left handed” materials to demonstrate novel RF and optical applications for Defense. Specific demonstrations include the reduction of UHF antenna size by a factor of 20 with no loss in gain and approaches for sub-wavelength focusing at IR wavelengths.
– Develop new functional material and devices that slow light pulses, resulting in opportunities such as tunable delay lines for optical signal processing, high-speed RF signal processing applications and single-photon quantum devices.

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	FY 2005	FY 2006	FY 2007
Materials for Logistics (Air, Water, Power)	35.138	48.000	51.032

(U) This thrust will apply novel materials and structures to reduce the logistics burden of the warfighter in the field. New materials and concepts for increasing the availability of portable power to the soldier are being investigated, as are approaches for deriving power from the environment for soldiers and sensors. Novel approaches for direct energy conversion from thermal sources such as submarine nuclear reactors are also being examined. New materials and designs will also be applied to the development of novel mesoscale engines (e.g., Stirling, water lubricated steam engines) that will provide needed power on the battlefield. Hybrid superconducting/cryogenic components will provide a new paradigm for power electronics for the "all electric" platforms of the future. Also, new hybrid concepts for long duration, unmanned underwater vehicles will be investigated along with the feasibility of open ocean, littoral and freshwater prototype fuel cell systems, capable of generating continuous, unattended electrical power for greater than 10 years. Other approaches to enzymatic based energy sources will also be examined as will unconventional power sources. Solar cells will be developed that will demonstrate at least 50% efficiency in an affordable, manufacturable photovoltaic (PV) device through the development and fabrication of novel components such as device-grade quality PV materials, electronic doping, nanostructure process control, and the integration of the process capabilities with current micro- and nano-fabrication tools. Finally, materials technologies will also be employed in novel approaches for obtaining and purifying water in the field.

(U) Program Plans:

- Design, develop, and demonstrate robustness of portable power sources in the 20 Watt power range suitable for several mission scenarios including: 1) a three hour micro air vehicle reconnaissance mission; 2) a three day land warrior mission; and 3) a ten day special operation forces mission.
- Develop and demonstrate enabling direct thermal to electric conversion technologies with potential for high (> 20%) conversion efficiencies and high (> 1 W/cm^2) power densities for DoD and commercial power generation applications.
- Demonstrate concepts for highly power-dense, man-portable kilowatt generators that will reduce the logistics burden for the soldier in the field.
- Develop and demonstrate in real military environment an efficient, low cost, 400 watt Stirling engine for Defense applications, including powering of small, motorized vehicles.
- Develop and demonstrate unique, energy-saving concepts for obtaining water from non-traditional sources (e.g. water-from-air), for the individual warfighter and small groups of soldiers.

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- Demonstrate materials and components for a hybrid superconducting power system for a terrestrial (>5 MW) application that has high efficiency and reliability and the potential for significantly reduced size (10x) and weight (5x).
- Develop novel rectifying antenna approaches that will allow efficient beaming of power between spacecraft.
- Demonstrate processes that can convert military waste directly into usable power for the military.
- Design bioelectrocatalysts that are compatible to both the environment of the fuel cell, the electrolyte, and electron transport to the electrode.
- Designed, fabricated and tested laboratory models for sediment mounted and water column microbial fuel cells.
- Designed, fabricated and tested preliminary sediment mounted and water column microbial fuel cells.
- Developed preliminary models for estimating power output as a function of microbial speciation and chemical reductant/reactant concentrations.
- Validate power output models in littoral environments.
- Explore unconventional power sources that might yield new, efficient approaches to providing power to the battlefield.
- Develop novel concepts for extremely high efficient solar cells (>50%) and novel solar cell configurations for battlefield deployment.
- Demonstrate efficiency of solar cell optics and converter technologies in high, mid, and low energy photon environments.
- Demonstrate an integrated solar cell of at least 10 cm2 area, delivering 500 W/m2.
- Establish techniques for suppression of neutron and gamma emission in compact alpha emitter nuclear power generators (a safety issue) and verify methods for suppression of radiation-induced damage in nuclear energy converter mechanisms.
- Exploit advances in nanotechnology to achieve battery systems with a 3X increase in energy density to 400 watt hours/kg, and a 5X increase in power density to 1000 watt/kg with a 30% decrease in weight.
- Develop novel power components (e.g., fuel cells, structural batteries) that have the potential for demonstrating energy densities in the range of 1000-1500 Watt-hours per liter (W-hr/l) for UUV applications.

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	FY 2005	FY 2006	FY 2007
Friction Stir Welding	1.300	0.000	0.000

(U) Program Plans:

- Continued to investigate the applicability of using Friction Stir Welding to join amorphous alloys without recrystallization.

	FY 2005	FY 2006	FY 2007
Strategic Materials	3.400	2.550	0.000

(U) Program Plans:

- Development continues on reliable, robust, repeatable, and cost effective Chemical Vapor Composite (CVC) SiC manufacturing process for high tech military, space, and industrial applications.

	FY 2005	FY 2006	FY 2007
Advanced Materials for Electromagnetic Devices	2.000	0.000	0.000

(U) Program Plans:

- Developed nanoscale mechanical spin switches using a unique nanofabrication capability.

	FY 2005	FY 2006	FY 2007
Cryo-Power Electronics Development for the All-Electric Ship Program	1.300	0.000	0.000

(U) Program Plans:

- Developed cryogenic electronics for the all electric navy through the establishment of a Cryogenic Electronics Center at Albany.

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	FY 2005	FY 2006	FY 2007
MMI/MBI Nanotechnology Solutions	2.000	0.400	0.000

(U) Program Plans:

- Investigating new approaches and accelerated the research of leading-edge nano-scale technologies for potential Defense applications.

	FY 2005	FY 2006	FY 2007
SEMATECH	5.000	0.000	0.000

(U) Program Plans:

- Established an advanced semiconductor prototyping capability for innovative micro-scale and nano-scale technologies.
- Developed approaches for processing and integration of soft and hard materials based on a silicon-centric platform.

	FY 2005	FY 2006	FY 2007
Gelled Fuels & Oxidizers	2.450	0.000	0.000

(U) Program Plans:

- Developed new gell-based fuels and oxidizers for advanced DoD propulsion applications.

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	FY 2005	FY 2006	FY 2007
Characterization, Reliability & Applications of 3-D Microstructures	0.000	1.800	0.000

(U) Program Plans:

– Continue the development of key technologies behind a packaging concept that uses a stacked multi-chip module approach to reduce interconnect length and increase physical connectivity between layers of electronics.

(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 Materials & Biological Technology PE 0602715E, Project MBT-02

COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Biologically Based Materials and Devices MBT-02	111.261	110.398	132.225	130.511	130.335	130.335	105.335

(U) Mission Description:

(U) This project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials, devices and processes as well as the commensurate influence of materials, physics and chemistry on new approaches to biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials to maintain performance, the use of biology's unique fabrication capabilities to produce structures that cannot be made any other way, the application of magnetic materials in biological applications, and the development of manufacturing tools that use biological components and processes for materials synthesis. It also supports a major thrust that will revolutionize the development of prosthetics for wounded soldiers.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Bioinspired and Bioderived Materials	48.111	44.000	48.000

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

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(U) Program Plans:

- Demonstrate biomimetic sensory prototypes and materials that collect electromagnetic olfactory and visual inputs.
- Define new, malleable materials that utilize biomimetic principles of design (e.g., emulate skin, bone, muscle, nerve endings and self repair features) for locomotion and actuation.
- Explore new bioinspired locomotion in robotic systems and develop power efficient, systems level bio-locomotion for mobility in rough/loose terrain and in environments not usually used for locomotion, i.e., vertical (>60°) and inverted surfaces.
- Develop new biomimetically based swimming devices that will double the speed for SEALS while decreasing energy consumed by a factor of eight.
- Develop new materials that will allow the demonstration of lightweight, compact, bio-inspired optical devices. Demonstrations will include a 30X zoom lens of a size to fly on the Pointer unmanned air vehicle (UAV) and a variable field of view (90-180 degrees) lens that will fly on the Dragon Eye UAV.
- Develop an initial understanding of fish (bony and elasmobranch) sensory and sensory-motor capabilities to provide the basis for developing associated biomimetic sensor systems.
- Develop a preliminary understanding of basic sensory and motor responses using both external and internal stimulation.
- Develop biomimetic sensor systems and demonstrate complex tasks such as acoustic and chemical homing and geometric search patterns.
- Demonstrate an integrated surveillance system using biomimetic sensor systems.
- Determine and quantify the mechanism of motor function, motor performance, and efficiency for several types of biomolecular motors through computational models and experimental measurements.
- Demonstrate the utility of biomotors for specific DoD applications including high sensitivity biosensors, high efficiency solar cells and the emulation of natural muscle activity.
- Exploit stealthy sentinels, including the development of critical materials/device interfaces to address teleoperation and autonomous navigation, for their ability to be remotely guided to operationally relevant sites and generate environmental information (chemical, biological, and visual).
- Develop material systems based on biological principles that distribute the force and displacement capability of a hydraulic system continuously throughout a structure. Demonstrate these materials in systems that require large forces at moderate bandwidth such as helicopter blades.

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- Develop signal transduction technology that directly converts biological macromolecular activity (sensing/binding/conformation changes) into an appropriate electrical or optical signal output for the development of biomimetically-based sensors (uncooled IR, optical, etc.).

	FY 2005	FY 2006	FY 2007
Biochemical Materials	48.000	43.398	53.225

(U) The Biochemical Materials thrust examines how breakthroughs in the understanding of biochemistry can drastically improve the survivability of soldiers. For example, examining the biochemistry of the brain during sleep deprivation can lead to new approaches for maintaining the cognitive function of soldiers in the face of sleep deprivation. The application of biochemical principles can also lead to techniques to allow the principles of biological organisms that survive in extreme environments to be exploited for the preservation of tissue and cells of interest to DoD. Finally, understanding the biochemical behavior of organs and tissues, including the interaction of energy with biology, can lead to significant advances in the medical treatment of the soldier on the battlefield.

(U) Program Plans:

- Demonstrate induced desiccation strategies for platelets and red blood cells that allow prolonged periods (> 24 months) of dry storage and recovery and evaluate efficacy of the blood products.
- Develop self-care medical technology to enable the warfighter in the battlefield to accelerate wound healing, internal clotting and pain relief to increase a soldier’s survivability on the battlefield.
- Develop an understanding of the biochemical and physiological causes of decreased cognitive performance during sleep deprivation through studying animal model systems, synaptic function, and transcranial magnetic stimulation (TMS).
- Demonstrate and validate approaches to develop biomaterials and other concepts that extend the cognitive performance capabilities of warfighters during extended periods of sleep deprivation and stress.
- Develop methods that are applicable to the battlefield environment for maintaining physical performance by nutritional and physical methods.
- Develop methods for regulating core body temperature and hydration to maintain physical performance and endurance when training.

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- Develop a lightweight version of the Life Support for Trauma and Transport (LSTAT) portable intensive care platform with innovative technologies to make the system available in the far forward battlefield for combat casualty care of wounded soldiers.
- Demonstrate full 3-D visual image representation carried on electronic dog tag that can be used to predict likelihood of survival from potentially lethal battlefield wound. Extend 3-D imaging approaches to a virtual autopsy capable of a more rapid and accurate post mortem wound assessment.
- Define and demonstrate new operating room technologies for the battlefield that reduce the needs for operating personnel.
- Develop devices to locate bleeding and stimulate the clotting process using acoustic energy.
- Develop methods for selectively reducing metabolic requirements in a reversible manner following injury in order to extend the period of survival from injury to initiation of treatment.
- Develop a device to allow automatic initiation of intravenous catheter in a battlefield environment even by unskilled personnel.
- Develop novel biochemical feedback mechanisms and nanotechnology based delivery systems to create auto-regulation feedback for any therapeutic or biochemical agent in order to prevent side effects due to variability in dosage.
- Implement new non-invasive biological sensors to create practical, prototype devices for using neurological signals to improve the throughput and accuracy of intelligence imagery analysis.

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	FY 2005	FY 2006	FY 2007
Bio-Fabrication	5.000	2.000	2.000

(U) The Bio-Fabrication (B-FAB) program will demonstrate the feasibility of using biochemical processes as a new nanofabrication toolset to synthesize and manufacture chemicals, materials, and devices of high value to the DoD. Such approaches would be useful as part of the nanostructure for highly efficient solar cells. Other targets for demonstration within this program include scalable technologies for opto-electronic materials and devices (GaN-InGaN-AlGaN and InP-GaP-AlP-AlInGaP materials; ultra-low-k dielectrics; Rf and photo-emissive devices), mechanical materials (super-tough fibers and associated composites), and site-directed-synthesis (in-package device fabrication). Key elements of this program include the development and utilization of biological components and/or processes for the fabrication of device-grade quality electronic/optical/mechanical materials, further development of these processes for electronic or optical doping, site-directed synthesis, and nanostructure process control, and finally the integration of the B-FAB process capabilities with current micro- and nano-fabrication tools for the fabrication of full-scale integrated electronic, optical, or mechanical proof-of-technology devices.

(U) Program Plans:

- Develop bioenabled routes for the fabrication of relevant electronic, optical, or structural materials. Demonstrate the essential capacity for the fabrication of the materials at the scale of interest (2-20nm range control).
- Develop computational, fabrication, and process control tools for the design, manipulation, and optimization of the bioprocess or bio-pathway with the target properties necessary for the fine-scale manipulation of bio-fabrication.
- Develop and demonstrate the capability to produce bio-fabricated materials with chemically and/or spatially modulated properties, possibly including controlled doping (n-type, p-type), stacked nano-layers, quantum dots, or 3-D articulated structures in a candidate electronic, optical, or mechanical device material.
- Demonstrate the integrability of bio-fabrication processes with current fabrication and/or micro-fabrication toolsets.
- Design, develop, and demonstrate integrated bio fabricated electronic, optical, or mechanical devices with improved or otherwise unattainable performance or cost characteristics.

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	FY 2005	FY 2006	FY 2007
Bio-Magnetic Interfacing Concepts (BioMagnetICs)	10.150	6.000	4.000

(U) The Bio-Magnetic Interfacing Concepts (BioMagnetICs) Materials program will develop and demonstrate novel capabilities for integrating nanomagnetics with biology and will demonstrate the advantages of magnetics as a powerful new transduction mechanism for detecting, manipulating, and controlling biological function in single cells and biomolecules. The state-of-the-art research "tools" that have allowed researchers to observe the most fundamental units of biology (cells, DNA, proteins, etc.) do not possess the resolution, precision, or high throughput capacity to enable manipulation and/or functional control of large numbers of cells and biomolecules. Such a capability would have a pervasive and paradigm shifting impact on future military and civilian applications of biotechnology including chem-bio detection, therapeutics, and medical diagnostics. Nanoscale magnetics offers the promise of a robust, non-invasive, non-destructive, multiplexing, and high throughput interface that is compatible with the nanometer scale at which the biochemistry of cellular function exists.

(U) Program Plans:

- Develop and demonstrate a portable, magnetics-based DNA detection and readout capability for rapid determination of specific biological warfare agents.
- Develop and demonstrate remotely addressable, magnetics-based biochemical sensors.
- Develop the capability to use magnetics to rapidly filter biotoxins from humans.

	FY 2005	FY 2006	FY 2007
Revolutionizing Prosthetics	0.000	15.000	25.000

(U) The goal of this program is to dramatically change the state of the art of prosthetics, moving them from crude devices with minimal capabilities to fully integrated, fully functional limb replacements. Current prosthetic technology generally provides only gross motor functions, with very crude approaches to control—essentially switches. This often makes it difficult for wounded soldiers to return to a normal life, let alone return to military service. The needed advances will be accomplished by exploiting the dramatic breakthroughs of the Human Assisted Neural

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Devices program (PE 0601101E, Project BLS-01) as well as advances in biointerfaces, structural and smart materials, microelectronics and MEMS, and information sciences.

(U) Program Plans:

- Demonstrate the ability to implement brain/neural control with sensory feedback in a control architecture that combines the kinetics and mechanics (degrees of freedom) of natural movement, including the realization of proprioception and reflex activity.
- Develop and demonstrate new materials, microprocessors, sensors and actuators that are both biocompatible and emulate form, function and response of natural biological limbs.
- Develop and demonstrate new distributed power sources that greatly improve the longevity of limb operation.
- Develop and demonstrate new approaches to limb healing and prosthetic integration that will dramatically decrease healing time and alleviate the discomfort of wearing prosthetic devices.
- Demonstrate a neurally controlled prosthetic limb that has the full functionality of a natural limb and transition to Walter Reed Medical Center.

(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 Electronics Technology PE 0602716E

COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	254.514	239.959	246.978	244.651	244.775	249.025	249.025
Electronics Technology ELT-01	254.514	239.959	246.978	244.651	244.775	249.025	249.025

(U) **Mission Description:**

(U) This program element is budgeted in the Applied Research budget activity because its objective is to develop electronics that make a wide range of military applications possible.

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

(U) The 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. Another thrust of the program element 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. Projects 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

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incorporating these components for such applications as low cost seamless pervasive computing, ultra-fast computing, and sensing and actuation devices. This project has five major thrusts:

- Electronics: The manipulation of electrons in digital, analog, and mixed signal circuits for sensing, processing, and communications. This thrust includes such programs as Advanced Digital Receiver, Advanced Microsystems Technology Program, Applications of Molecular Electronics, Clockless Logic, Feedback-Linearized Microwave Amplifiers, High Frequency Wide Band Gap Semiconductor Electronics Technology, High Power Wide Band Gap Semiconductor Electronics Technology, Metamorphic Computing, Advanced Digital Receiver Technology, Quantum Entanglement Science and Technology, Robust Integrated Power Electronics, Submillimeter Wave Imaging, Technology for Frequency Agile Digitally Synthesized Transmitters, Trusted Uncompromised Semiconductor Technology, Design Tools for 3-Dimensional Electronic Circuit Integration, and Processing Algorithms with Co-design of Electronics.

- Photonics: The generation, detection, and modulation of photons for imaging, communications, and sensing. This thrust encompasses the following programs: Nanowire Electronics and Optoelectronics, Adaptive Focal Plane Arrays, Advanced Precision Optical Oscillator, Analog Optical Signal Processing, Bio-Electronics and Photonics, Chip-to-Chip Optical Interconnects, Linear Photonic RF Front End Technology, Optical Arbitrary Waveform Generation, Solid State Imager/Extended Range Materials, and Ultrabeam.

- MicroElectroMechancial Systems (MEMS): Exploitation of the processing tools and materials from semiconductor technology to build electro-mechanical structures at the micro- and nano-scale. The MEMS thrust encompasses: Adaptive Focal Plane Arrays, 3-Dimensional Microelectromagnetic RF Systems, and Radio Isotope Micropower Sources.

- Architectures: Exploitation of new arrangements of materials, devices, and circuits to increase performance or reduce power. Programs under this thrust include: HyperX, Terahertz Imaging Focal-Plane Technology, and Polymorphous Computing Architectures.

- Algorithms: The exploitation of insights into mathematical constructs for data representation, process control, and discrimination routines by leveraging knowledge of Microsystem hardware operation. Programs under this thrust include: Optoelectronics for Coherent Optical Transmission and Signal Processing, and Multiple Optical Non-redundant Aperture Generalized Sensors.

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(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Advanced Digital Receiver	2.800	2.200	0.000

(U) The Advanced Digital Receiver program will leverage and improve Analog to Digital Converter (ADC) technology to develop Digital Receivers with greatly enhanced performance. Goals include reducing size, weight and power by an order of magnitude, enhancing programmability, flexibility and performance, reducing life cycle cost, and developing ADCs with 16 effective bits, 100 MHz instantaneous bandwidth and >100 dB spurious free dynamic range (SFDR).

(U) Program Plans:
- Demonstrate 1st Pass Sigma-delta Modulator in test fixture.
- Demonstrate 2nd Pass Sigma-delta Modulator in test fixture with ADC-DAC Iteration 1.
- Demonstrate Real-time Digital Receiver Operation by Benchtop Integration of Best Sigma-delta Test Fixture and WAR Decoder Test Fixture.
- Demonstrate 3rd Pass Sigma-delta Modulator in test fixture with ADC-DAC Iteration 2.
- Demonstrate Real-time Digital Receiver Module Prototype (provide 5 modules).

	FY 2005	FY 2006	FY 2007
Advanced Microsystems Technology Program	5.000	5.000	5.000

(U) This program will explore a range of advanced microsystem concepts well beyond existing current technologies. The program will focus on technologies that exploit three-dimensional structures, new materials for Gieger mode detectors, advance patterning, and extreme scaling in silicon devices. Insights derived in these areas will be exploited in future program initiatives.

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(U) Program Plans:

- Establish and exercise multi-project wafer runs for 3D integrated circuits.
- Demonstrate bonding and functionality of Silicon-On-Insulator circuits to Indium Phosphide detectors.
- Extend maskless multiple exposure system to 2x smaller features.
- Demonstrate photoresist capable of multiple in-situ exposure with enhanced resolution.
- Demonstrate sub-35 nm half-pitch interometric liquid exposure capability.
- Prepare report analyzing prospects for beyond roadmap technologies.
- Deliver data on ultra-low voltage operation of Silicon CMOS for DoD applications.

	FY 2005	FY 2006	FY 2007
Applications of Molecular Electronics (MoleApps)	4.233	10.710	2.110

(U) The goal of the MoleApps program is to extend the capabilities being developed in the current Moletronics program to demonstrate the computational processing capabilities of molecular electronics in a system that integrates memory with control logic and data paths. A demonstration processor will be designed and built that can interpret a simple high-level language. This approach will allow the use of simpler processor designs to demonstrate the advantages of nano-scale molecular electronics that do not have the conventional circuitry overhead associated with modern pipeline chip designs.

(U) Program Plans:

- Construct combinatorial logic functions assembled from molecular-scale components.
- Use small-scale integration (SSI) to build combinatorial logic functions using molecular-scale components.
- Construct sequential logic/finite-state machine assembled from molecular-scale components.
- Add registers or latches in communication with combinatorial logic arithmetic functions.
- Use medium-scale integration (MSI) to construct sequential logic/finite-state machine assembled from molecular-scale components.
- Demonstrate molecular electronics sensor array with 50 sensors per square micron capable of detecting 7 agents in 10 seconds with probability of detection > 0.99 and false positive <10^-5.

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	FY 2005	FY 2006	FY 2007
Clockless Logic	3.900	4.700	2.500

(U) The goal of the Clockless Logic program is to develop techniques to reduce the amount of design resources required in chip design and significantly reduce the power and noise to provide improved system operation. Clockless methods will provide more efficient designs especially for military systems with demanding space, weight, power, and noise constraints.

(U) Program Plans:

- Develop method for design of complex chips using clockless logic.
- Enhance tools and methods for design of clockless logic circuits and systems.
- Identify and design complex chips with significant potential for improved system performance and reduced design times.
- Apply clockless design methods to programmable logic devices to provide significant potential for improved system performance and reduced design times.
- Demonstrate performance enhancements of complex chip enabled by clockless logic in radar or similar testbed.

	FY 2005	FY 2006	FY 2007
Energy Starved Electronics (ESE)	0.000	0.750	1.000

(U) The Energy Starved Electronics (ESE) program seeks to develop ultra low power IC devices and circuit design methods for military electronics that must operate where power is severely limited. The objective of the program is to mature both device technology and design techniques to allow operation of devices in the sub threshold (very low voltage) regime beyond where the circuit devices normally operate. The ability to operate an ultra-low power circuit while still maintaining modest performance will enable the successful implementation of many long lived operational systems such as remote sensor networks as well as small unit communications and other wireless applications. The goal of the program will be a 100X improvement in energy per operation over conventional designs operated at low voltage.

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(U) Program Plans:
- Develop a robust design methodology and sub-threshold standard cell library.
- Implement a feedback control scheme to achieve operation at the minimum energy dissipation point.
- Demonstrate ultra-dynamic voltage scaling methodology that allows performance and energy to be traded-off over several orders of magnitude.
- Establish fundamental limits of energy dissipation of digital circuits taking into account process variations and device impairments (e.g., leakage).

	FY 2005	FY 2006	FY 2007
High Frequency Wide Band Gap Semiconductor Electronics Technology	10.352	20.000	22.000

(U) The High Frequency Wide Band Gap Semiconductor Electronics Technology program is developing high performance, cost effective high power electronic devices that exploit the unique properties of wide band gap semiconductors. Specifically, 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) Program Plans:
- Develop bulk and surface process technologies for reducing or mitigating crystallographic defects in wide band gap materials.
- Develop semi-insulating substrates for high frequency devices.
- Design high power enclosures for microwave electronic assemblies.
- Demonstrate large periphery high power devices suitable for microwave and mm-wave operation.
- Demonstrate process reproducibility and minimization of yield limiting factors.
- Establish device characterization for very high power solid-state amplifiers.
- Demonstrate 100 mm Silicon Carbide (SiC) and wide band gap alternate substrates with less than 80 micropipe/cm^2 and resistivity 10^6 ohms-cm.
- Demonstrate epitaxial processes that yield + 3 percent uniformity over 75 mm wide bandgap substrates.

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- Initiate thermal management study to determine best packaging approach for high power, high frequency microwave and millimeter wave transistors.
- Demonstrate 100 mm SiC and wide band gap alternate substrates with less than 40 micropipe/cm^2 and resistivity 10^7 ohms-cm.
- Demonstrate epitaxial processes that yield + 1 percent uniformity over 100 mm wide bandgap substrates.
- Identify fabrication processes for robust microwave and mm-wave devices.
- Identify thermal management concepts to sustain more than 1 KW/cm2 power density in high power devices.
- Optimize wide band gap semiconductor materials to achieve 100 mm substrates with less than 10 micropipe/cm^2 and resistivity greater than 10^7 ohms-cm at room temperature.
- Demonstrate fabrication processes for robust microwave and mm-wave devices with RF yields greater than 70 percent.
- Demonstrate thermal management concepts to sustain more than 1KW/cm^2 power density in high power devices.

	FY 2005	FY 2006	FY 2007
High Power Wide Band Gap Semiconductor Electronics Technology	18.827	10.505	12.000

(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) Program Plans:

- Develop low defect conducting Silicon Carbide (SiC) substrate consistent with yielding 1 cm^2 devices.
- Develop lightly doped, thick (more than 100 micron) SiC epitaxy with low defects to enable 10 kV class power devices.
- Develop low on-state resistance SiC diodes capable of blocking 10 kV.
- Demonstrate SiC wafer and thick epitaxy with less than 1.5 catastrophic defects per cm^2 consistent with 10 kV reverse blocking.
- Initiate work on Megawatt class SiC power device able to switch at more then 100 kHz.
- Initiate work on packaging of high power density, high temperature SiC power electronics.
- Demonstrate megawatt Class SiC power devices.

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- Demonstrate high power density packaging for greater than 10 kV operations.
- Develop integrated power control logic compatible with high temperature and power SiC power devices.

	FY 2005	FY 2006	FY 2007
HyperX	0.000	2.396	2.000

(U) Many Department of Defense (DoD) systems require processing and analysis of vast amounts of high-dimensional data in the field. The HyperX program will provide the capability for high performance signal processing at significantly lower power in a reconfigurable architecture. The focus of the program is to provide the military with a reconfigurable integrated circuit technology that can achieve high performance application-specific real time signal processing at low enough power to be suitable for embedded applications. In these cases, where severe constraints on power preclude the use of general purpose processing solutions, HyperX chips will provide more than an order of magnitude (10x) increase in both power and throughput performance over the current state-of-the-art reconfigurable Field Programmable Gate Array (FPGA) and general programmable processors.

(U) Program Plans:

- Demonstrate a novel, reconfigurable IC with significant improvement over current programmable and reconfigurable IC technology.
- Verify performance of HyperX IC fabric (operate at $\geq$ 500MHz and consume $\leq$ 250milliwatts).
- Develop Integrated Hardware/Software Design Environment Software.

	FY 2005	FY 2006	FY 2007
Metaphoric Computing	0.000	0.000	5.000

(U) Metaphoric computing is a dramatically different approach to computation than the predominant paradigm using digital representation and CMOS digital circuits consisting of logic gates. The conventional digital computing systems work by employing binary data representation and mapping the physics of CMOS transistors on the lowest level computation, namely the logic gate. Metaphoric computing exploits the physics of

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electronic and photonic systems to enable implementation of complex signal processing algorithms in real time on power-limited platforms. Similarly, modeling and simulations of nonlinear dynamical systems will be accelerated by many orders of magnitude by employing a physics-based approach to computation entailed in metaphoric computing initiative.

(U) Program Plans:

- Design photonic systems to display sophisticated dynamic behavior that is described by nonlinear partial differential equations.
- Transform equations to another set of equations that describe spread of disease or turbulent fluid flow around complex structure.
- Generate and manipulate asynchronous pulse train that is used to represent incoming signals over a wide dynamic range.
- Implement signal processing operation of Independent Component Analysis that is useful in blind signal separation problems.

	FY 2005	FY 2006	FY 2007
Nanowire Electronics and Optoelectronics	0.000	0.000	3.000

(U) The Nanowire Electronics and Optoelectronics program will synthesize, characterize, and apply new nanowire technologies for electronic, optoelectronic, and sensor applications which will enable new types of high-performance, heterogeneous micro- and nanosystems. Additional new types of optoelectronic devices, interconnections, and nanodisplays are also envisioned. Nanowire cell probes capable of reporting intracellular transport processes may open a new type of *in vivo* cellular biosensing for the early detection of BW agent exposure. The program goal is to extend successful nanowire materials synthesis concepts on Silicon substrates into new micro- and nanosystems applications.

(U) Program Plans:

- Achieve controlled materials synthesis, patterning, and control of interface properties.
- Use low-temperature vapor-liquid-solid (VLS) growth of Gallium Arsenide on a lattice-mismatched Silicon substrate.
- Use nanodot nucleation surfaces to initiate vertical nanowire growth.

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	FY 2005	FY 2006	FY 2007
Advanced Digital Receiver Technology (ADRT)	0.000	0.000	4.000

(U) Aggressively exploiting the pioneering breakthroughs of the Advanced Digital Receiver Technology (ADRT) program, the ADRT program will greatly extend its impact by integrating them into scalable Si-Ge technology (the people's material system). This program will create the next generation Analog-to-Digital Converters (ADC) in low power decoder chip integrated into a compact flip chip package.

(U) Program Plans:
- Direct RF sampling strategies for 1-20 GHz input range.
- Correct nonlinear errors of full operational bands.
- Devise and optimize SiGe/CMOS monolithic RF noise shaping modulator.

	FY 2005	FY 2006	FY 2007
Quantum Entanglement Science and Technology (QuEST)	22.280	24.703	24.110

(U) The Quantum Entanglement Science and Technology (QuEST) program, formerly called the Focused Quantum Systems (FoQuS) program, will explore all facets of the research necessary to create new technologies 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. Expected applications include: new improved forms of highly secure communication; faster algorithms for optimization in logistics and wargaming; highly precise measurements of time and position on the earth and in space; and new image and signal processing methods for target tracking. Technical challenges include: loss of information due to quantum decoherence; limited communication distance due to signal attenuation; limited selection of algorithms and protocols; and larger numbers of bits. Error correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Signal attenuation will be overcome by exploiting quantum repeaters. New algorithm techniques and complexity analysis will increase the selection of algorithms, as will a focus on signal processing. The QuEST program is a broad-

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based program that will continue to explore the fundamental open questions, the discovery of novel algorithms and the theoretical and experimental limitations of quantum processing as well as the construction of efficient implementations.

(U) Program Plans:

- Refine 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.
- Integrate improved single and entangled photon sources and detectors into existing quantum communication networks.
- Investigate alternative designs, architectures and devices for quantum communication and demonstrate high-rate (1Gbit/sec) quantum-secure communication over a single link; transition quantum-secure communication to existing DoD mobile testbed.
- Investigate unresolved fundamental issues related to quantum information science.
- Employ qubit architectures to demonstrate an application of interest to the DoD (e.g., quantum repeater, secure metropolitan-area network).
- Demonstrate interoperation between multiple qubit types to interconnect quantum communications links.

	FY 2005	FY 2006	FY 2007
Robust Integrated Power Electronics (RIPE)	2.841	7.580	8.882

(U) The RIPE program will develop new semiconductor materials, devices, and circuits that enable highly compact, highly efficient electronic power converter modules. These new modules will be capable of providing up to 50kW of power per module at a power density of 500W/cubic inch. Based on fundamental material properties, the new power modules will be capable of operating in harsh environments. These new power converters will reduce the launch weight of space-based platforms by hundreds of pounds and will enable new modes of operation where the power conversion is done at the point of load and provides high quality power to payloads. Application of RIPE on Naval surface ships would result in a significant reduction of power supply weight; allowing for additional electronic components and/or weapons.

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(U) Program Plans:

- Perform concept study to define opportunities for smart power and the potential for integrating silicon carbide, or other wide bandgap semiconductor, with silicon electronics.
- Identify key technical challenges and quantity impact of potential platforms.
- Identify compelling applications.
- Select and optimize wide bandgap materials and processes for smart power circuits.
- Develop integration techniques for silicon carbide, or other wide bandgap semiconductor, onto silicon and/or silicon onto silicon carbide.
- Develop low on-resistance, fast switching silicon carbide power devices with hybrid control electronics.

	FY 2005	FY 2006	FY 2007
Submillimeter Wave Imaging FPA Technology (SWIFT)	0.000	11.850	8.260

(U) The Submillimeter Wave Imaging FPA (Focal Plane Array) Technology (SWIFT) program will develop revolutionary component and integration technologies to enable exploitation of this spectral region. A specific objective will be the development of a new class of sensors capable of low-power, video-rate, background and diffraction limited submillimeter imaging.

(U) Program Plans:

- Develop compact, efficient, and high-power THz sources using new electronic and frequency conversion approaches.
- Develop sensitive and large format receiver arrays, advanced integration, and backend signal processing techniques.
- Develop and demonstrate a submillimeter focal plane imager.

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Technology Efficient, Agile Mixed Signal Microsystem (TEAM)	15.732	15.570	10.000

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

(U) Program Plans:
- Develop and demonstrate nanoscale silicon-based structures and associated fabrication processes to achieve high-speed analog/RF functions.
- Optimize device and process parameters for high speed mixed signal circuits.
- Produce test devices for analog/RF parameter extraction.
- Demonstrate Complementary Metal Oxide Semiconductor (CMOS) compatible fabrication processes that can yield integration levels greater than 10,000 nanoscale devices.
- Initiate highly parallel densely interconnected architectures with micron-sized vias penetrating stacks of detectors, analog, mixed signal and digital circuits.
- Demonstrate operation of high performance mixed signal circuits based on nanoscale devices.
- Demonstrate low noise interface and high isolation (up to 100 db) between high performance analog circuits and associated digital signal processing.
- Fabricate mixed signal systems on chip with nanoscale transistors.

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	FY 2005	FY 2006	FY 2007
Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST)	19.591	14.000	10.000

(U) The TFAST program (Ultra High Speed Circuit Technology) will develop super-scaled Indium Phosphide (InP) Heterojunction Bipolar Transistor (HBT) technology compatible with a ten-fold increase in transistor integration for complex mixed signal circuits. Phase I will establish the core transistor and circuit technology to enable the demonstration of critical small scale circuit building blocks suitable for complex mixed signal circuits operating at speeds three times that currently achievable and ten times lower power. Phase II will extend the technology to the demonstration of complex (more than 20,000 transistors) mixed signal circuits with an emphasis on direct digital synthesizers for frequency agile transmitters.

(U) Program Plans:

- Develop material and process technology for super-scaled InP double heterostructure bipolar transistors (DHBTs). Technical approaches will leverage the process technology used in the silicon, and silicon germanium, industry to produce a planar, highly scalable InP HBT.
- Extend the core DHBT and interconnect technology with the implementation of complex mixed signal circuits.
- Develop super-scaled InP HBT processing technology for 0.25 micron and below.
- Develop high current, planar, InP HBTs compatible with high levels of integration.
- Develop greater than 100 GHz mixed signal circuit building blocks.
- Demonstrate record performance InP HBTs in a planar process for complex mixed signal circuits.
- Demonstrate critical mixed signal building block circuit operating at more than 100 GHz.
- Develop circuit designs for direct digital frequency synthesizers (DDS) operating with clock speed up to 30 GHz.
- Define circuit designs and layouts for mm-wave DDS and related complex mixed signal circuits.
- Develop full circuit capability using super-scaled InP HBTs in complex (more than 20,000 transistor) circuits.
- Establish device models and critical design rules.

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	FY 2005	FY 2006	FY 2007
Feedback-Linearized Microwave Amplifiers	0.000	0.000	5.000

(U) Modern military platforms are requiring increased dynamic range receivers for their onboard communications, in both radar and electronic warfare antenna systems. The goal of this program is to develop RF amplifiers with revolutionary increased dynamic range receivers through the use of linear negative feedback. This program will develop the core technologies and components that may be used as building blocks and/or modules in future system applications. This program will leverage technologies from the TFAST program.

(U) Program Plans:

- Ensure stability of closed-looped amplifier while not increasing internal latencies from transistors and layout parasites.
- Address design challenges related to negative feedback.
- Investigate avoidance of circuit oscillation.

	FY 2005	FY 2006	FY 2007
Terahertz Imaging Focal-Plane Technology (TIFT)	6.625	10.000	15.000

(U) The TIFT program, formerly Imaging Coherent Optical Radar, will demonstrate large, multi-element (> 40K pixels) detector receiver focal plane arrays that respond to radiation in the THz band (> 0.557 THz). The sensor system will be able to operate effectively at standoff range (> 25m) with a high spatial resolution (< 2 cm) limited only by beam diffraction. The imaging receiver will produce a two-dimensional (2D) image in which each pixel records the relative intensity of the THz radiation received on the focal plane within the appropriate section of the field of view of the scene being sensed. The program will achieve intensity sensitivities as close as possible to the thermal background limit at room temperature. The minimal acceptable acquisition time is video-rate (30 Hz). The receiver may be either passive or active (including THz time domain methods). The size, weight, and electrical power requirements will be consistent with portability.

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(U) Program Plans:

- Demonstrate revolutionary component and integration technologies necessary for the development of a diffraction-limited, video-rate THz (at least 0.557 x 10^{12}Hz) frequency imaging imager.
- Demonstrate a compact THz source achieving at least 10 mW of average power and 1% wall plug efficiency, as required for active illumination and/or for local oscillators in heterodyne or homodyne detection schemes.
- Demonstrate a THz receiver capable of achieving a noise equivalent power of less than 1 pW/Hz $^{1/2}$ as measured with an integrated acquisition time of no more than 30 ms and a pre-detection bandwidth of no more than 50 GHz, as required in order to achieve a system-level noise equivalent delta temperature of 1K or better.

	FY 2005	FY 2006	FY 2007
Trusted, Uncompromised Semiconductor Technology (TrUST)	0.000	0.000	5.000

(U) The TrUST program will explore techniques to insure Integrated Circuits (IC's) of interest to the DoD can be certified as trustworthy after fabrication. These efforts will compliment other maskless lithography and verifiable design programs. The first thrust will develop new tools and techniques for rapidly analyzing fabricated circuits and comparing the circuit topology to that of the design produced at the trusted design source. The second thrust will exploit emerging research in 3D stacked and monolithic circuits to distribute, or segment, a complex IC into smaller sub-circuits. In this way, the sub-circuits can be fabricated separately, making it more difficult to compromise the complete circuit and making it easier to characterize each circuit for trustworthiness. This approach will also leverage the performance advances projected for 3D architectures. The final thrust will explore novel ways to add "hardware jacket" to complete IC's that will service to monitor the circuits' performance and raise a flag if unspecified operations are encountered.

(U) Program Plans:

- Develop new tools and techniques for rapidly analyzing fabricated circuits and comparing the circuit topology to that of the design produced at the trusted design source.
- Exploit emerging research in 3D stacked and monolithic circuits to distribute, or segment, a complex Integrated Circuits (IC) into smaller sub-circuits.

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- Explore novel ways to add "hardware jacket" to complete ICs that will service to monitor the circuits' performance and raise a flag if unspecified operations are encountered.
- Develop distributed circuit architectures by building trusted circuits through 3D segmented designs.
- Explore Integrated Circuit monitoring for deployed performance verification.

	FY 2005	FY 2006	FY 2007
Adaptive Focal Plane Arrays (AFPA)	9.503	12.170	10.039

(U) The goal of this program is to demonstrate high-performance focal plane arrays that are widely tunable across the entire infrared (IR) spectrum (including the short, middle and long-wave infrared bands), thus enabling "hyperspectral imaging on a chip." The Adaptive Focal Plane Array (AFPA) program will also allow for broadband Forward Looking Infrared (FLIR) imaging with high spatial resolution. These AFPAs will be electrically tunable on a pixel-by-pixel basis, thus enabling the real-time reconfiguration of the array to maximize either spectral coverage or spatial resolution. The AFPAs will not simply be multi-functional, but rather will be adaptable by means of electronic control at each pixel. Thus, the AFPAs will serve as an intelligent front-end to an optoelectronic microsystem. The AFPA program outcome will be a large format focal plane array that provides the best of both FLIR and Hyper-Spectral Imaging (HSI).

(U) Program Plans:
- Develop component technology (tunable IR photodetectors).
- Integrate detector array.
- Demonstrate pixel-by-pixel electrical tunability in IR.
- Demonstrate AFPA prototype field using a large format array.

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	FY 2005	FY 2006	FY 2007
Advanced Precision Optical Oscillator (APROPOS)	7.600	9.700	7.200

(U) The APROPOS program will leverage advances in materials and lasers to develop new precision microwave-stable local oscillators with extremely low phase noise (up to 50 dB better than the current state of the art) at small offsets from microwave carrier frequencies. This capability will enhance performance of radar, electronic warfare and communications systems in weak signal detection at increased stand off ranges, slow moving target detection, clutter suppression, and electronic warfare fingerprinting (specific emitter identification).

(U) Program Plans:

– Improve phase noise power spectral density by 25 dB and prove the utility of multi-line laser cavities and opto-electronic oscillators.
– Identify and characterize environmental susceptibilities and define path to 50 dB improvement over state of the art.
– Demonstrate 50 dB improvements in lab setting.
– Develop miniaturization approach and packing concept to mitigate environmental susceptibilities.
– Miniaturize devices in ruggedized packages.
– Demonstrate performance in tactical environments by inserting in system testbeds.

	FY 2005	FY 2006	FY 2007
Analog Optical Signal Processing (AOSP)	7.969	3.989	0.000

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

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(U) Program Plans:

- Perform analysis of analog signal characteristics of military RF systems.
- Create, model and simulate new photonic-based optical signal processing techniques of ultra-high bandwidth analog signals.
- Evaluate anticipated system performance improvements due to novel signal processing algorithms and determine the resulting photonic component performance requirements.
- Test and evaluate signal processing techniques of analog signals.
- Evaluate photonic component performance requirements.
- Design, fabricate and test individual photonic components capable of meeting RF signal processing requirements.
- Determine the most promising approaches for development of integrated, chip-scale components using new materials and processing technologies.
- Determine interface requirements.
- Evaluate the suitability of the new components for use in prototype modules.
- Down-select to the most promising approaches and begin prototype module assembly.
- Construct testbeds capable of fully characterizing the photonic-based RF signal processing components.

	FY 2005	FY 2006	FY 2007
Bio-Electronics and Photonics	0.000	0.000	6.000

(U) The Bio-Electronics and Photonics program will demonstrate new capabilities in protein- and DNA-based optical and electronic media that will address the challenge of high density storage without loss of rapid access time.

(U) Program Plans:

- Develop new synthetic or engineered natural chromophores that possess both sufficient chromophore density and optical cross-section.
- Use DNA as a low loss cladding layer for electro-optic (EO) devices, i.e., waveguides.

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- Demonstrate sub-wavelength addressing techniques.
- Demonstrate high density, rapid access logic gates and memories.

	FY 2005	FY 2006	FY 2007
Chip-to-Chip Optical Interconnects	6.554	4.709	5.000

(U) Continuing advances in integrated circuits technology are expected to push the clock rates of Complimentary Metal Oxide Semiconductor (CMOS) chips into 10GHz range over the next five-to-seven years. At the same time, copper-based technologies for implementing large number of high speed channels for routing these signals on a printed circuit board and back planes are expected to run into fundamental difficulties. This performance gap in the on-chip and between-chip interconnection technology will create data throughput bottlenecks affecting military-critical sensor signal processing systems. To address this pressing issue, this program will develop optical technology for implementing chip-to chip interconnects at the board and back plane level.

(U) Program Plans:

- Develop high-linear density, low loss optical data transport channels that can be routed to ~1 meter distance in a geometric form factor compatible with a printed circuit board.
- Demonstrate high speed (faster then 10 GBps), low power (less then 50 mW) optical transmitter/receivers.
- Integrate optical transmitters/receivers and optical data paths with electronic packaging and manufacturing approaches.

	FY 2005	FY 2006	FY 2007
Linear Photonic RF Front End Technology (PHOR-FRONT)	0.000	0.000	6.594

(U) The goal of this program is to develop photonic transmitter modules that can adapt their frequency response and dynamic range characteristics to mate with the full spectrum of narrow-band and broadband microwave transmission applications covering the 2 MHz – 20 GHz range. These field programmable, real-time adaptive photonic interface modules will find application in high dynamic range communications, radar and Electronic Warfare (EW) antenna applications.

(U) Program Plans:

- Develop photonic transmitter modules to allow tunable frequency and impedance matching to arbitrary antenna structures, with adaptive pre-distortion, feedback and feed-forward linearization schemes.
- Transition into airborne, space and maritime platforms where wideband communications, radar and EW apertures, with size, weight and power advantages are needed.

	FY 2005	FY 2006	FY 2007
Optical Arbitrary Waveform Generation (OAWG)	0.000	6.265	10.282

(U) The ultimate vision for the Optical Arbitrary Waveform Generator (AWG) program is to demonstrate a compact, robust, practical, stable octave-spanning optical oscillator, integrated with an encoder/decoder capable of addressing individual frequency components with an update rate equal to the mode-locked repetition rate. This would provide an unprecedented level of performance for optical systems, and enable numerous high level applications, including sub-diffraction-limited imaging and ultra-wideband optical communications.

(U) Program Plans:

- Demonstrate technology for producing (and detecting) arbitrary coherent optical waveforms with > with positive linear chirp of 1000 GHz with fidelity of <5% least-squared deviation from mathematical ideal waveform, accounting for interference from adjacent waveforms.
- Demonstrate production of single-cycle, 3 GHz square wave (pulse train duration of 0.67 ns) with fidelity of <1% least-squared deviation from mathematical ideal waveform.

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	FY 2005	FY 2006	FY 2007
Optoelectronics for Coherent Optical Transmission & Signal Processing	0.000	4.995	6.705

(U) The goal of this program is to develop optoelectronic component technologies that enable increased physical layer security in optical transmission systems through the synergistic use of coherent optical technologies and high-speed electronics. Secure, high-capacity free-space communications is essential for the transformational communications architecture to be realized. Both digital and analog transmission will be considered.

(U) Program Plans:

- Develop compact stable lasers, local oscillators and frequency combs (<10 Hz linewidths with <1 kHz long-term accuracy), high-speed quadrature optical modulators (>6 bit/s/Hz spectral efficiency with 100 GHz signaling rates), and digital homodyne receivers.
- Transition into airborne, space and maritime platforms where secure, high-capacity military optical networks for targeting and imaging are coveted.

	FY 2005	FY 2006	FY 2007
Solid State Imager/Extended Range Materials/Long WL High Gain Optical Sensors	0.000	2.000	3.000

(U) Imaging in the near-to-mid wave spectral region provides the capability to penetrate atmospheric obscurants and image where conventional sensors cease to generate data or produce severely degraded information. New materials and concepts for solid state imaging are essential to take advantage of this novel imaging regime, providing the capability to see where others cannot. This development includes new material concepts, such as quantum dots and superlattice structures, which offer the ability to precisely tailor the spectral band, and potentially operate at or near room temperature. In addition, new solid state sensor concepts will be developed to spatially and temporally co-register each pixel in the image to implement novel on-chip processing for noise cancellation and clutter rejection in severely degraded environments.

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(U) Program Plans:
- Develop new material concepts.
- Develop new solid state sensors concepts.

	FY 2005	FY 2006	FY 2007
Ultrabeam	3.539	1.344	1.000

(U) The UltraBeam program involves conversion of femtosecond duration ultraviolet laser light pulses to x-rays and the study of intense x-ray pulse propagation in various media.

(U) Program Plans:
- Validate the scientific feasibility of the conversion and propagation processes.
- Demonstrate a working laboratory model involving higher beam energies and shorter pulse durations.

	FY 2005	FY 2006	FY 2007
3-D Microelectromagentic RF Systems (3-D MERFS)	7.524	5.800	3.960

(U) The 3-D Microelectromagnetic RF systems (3-D MERFS) program will develop complete millimeter wave (MMW) active arrays on a single or a very small number of wafers. The program will exploit new technologies being developed commercially that allow Gallium Arsenide active components to be placed on Silicon wafers, and advances in Indium Phosphide and Silicon Germanium that may allow an entire MMW Electronically Scanned Array (ESA) to become very highly integrated on a sandwich of wafers. At lower frequencies, the large spacing between radiating elements precludes the efficient use of the wafer real estate for fabricating the entire ESA, but at Ka and W- bands, the element spacing is small enough to allow an ESA to be made with active transmit/receive chips and control circuits on one layer, radiators on another, and a feed system on a third. This could potentially make them very cheap, compact, lightweight and reliable. This would enable the development of new MMW ESAs of a six inch diameter or less for seekers, communication arrays for point-to-point communications, sensors for smart munitions,

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robotics and small remotely piloted vehicles. This program will build upon technology developed under the Vertically Interconnected Sensor Array program.

(U) Program Plans:
- Survey the emerging commercial MMW technology base and identify the best candidate processes for the MMW ESA application.
- Develop the optimal ESA architectures for wafer fabrication.
- Determine requirements for MMW ESAs that match the expected performance.
- Design, build, and test candidate ESA designs.
- Design, build, and test full ESA seeker or other system using the wafer fabrication technology.

	FY 2005	FY 2006	FY 2007
Chip Scale Atomic Clock	21.532	4.023	5.000

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

(U) Program Plans:
- Demonstrate feasibility and theoretical limits of miniaturization of cesium clock.
- Demonstrate subcomponent fabrication, including atomic chamber, excitation and detection function.
- Demonstrate design and fabrication innovation for atomic-confinement cell and for GHz resonators suitable for phase locking or direct coupling with atomic confinement cell.

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	FY 2005	FY 2006	FY 2007
Radioisotope Micropower Sources (RIMS)	8.392	11.137	12.014

(U) This effort will seek to develop the technologies and system concepts required for safely producing electrical power from radioisotope materials for portable and mobile applications, using materials that can provide passive power generation. There will also be research in compact radioisotope battery approaches that harness MEMS technology to safely and efficiently convert radioisotope energy to either electrical or mechanical power while avoiding lifetime-limiting damage to the power converter caused by highly energetic particles (e.g., such as often seen in previous semiconductor approaches to energy conversion). The goal is to provide electrical power to macro-scale systems such as munitions, unattended sensors, and weapon systems, RF ID tags, and other applications requiring relatively low (up to tens of milliwatts) average power.

(U) Program Plans:

- Develop and demonstrate core technologies of radioisotopes and the manufacturing of alpha and/or beta capture mechanisms to show advances in power output at high conversion factors, material stability, and particle capture in a small form factor with high conversion efficiencies, while operating within safety considerations and limitations.
- Demonstrate reasonable longevity for the chosen radioisotope-to-electrical or radioisotope-to-mechanical power conversion technique.
- Demonstrate actual, long-lasting power generation by the chosen radioisotope-to-electrical or radioisotope-to-mechanical conversion method.

	FY 2005	FY 2006	FY 2007
Design Tools for 3-Dimensional Electronic Circuit Integration	9.718	10.649	10.272

(U) This program will develop a new generation of Computer Aided Design (CAD) tools to enable the design of integrated three-dimensional electronic circuits. The program will focus on methodologies to analyze and assess coupled electrical and thermal performance of electronic circuits and tools for the coupled optimization of parameters such as integration density, cross talk, interconnect latency and thermal management. The goals of this initiative are to develop a robust 3-D circuit technology through the development of advanced process capabilities and the design

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tools needed to fully exploit a true 3-D technology for producing high performance circuits. The deliverables from this program will have a significant impact on the design of mixed signal (digital/analog/RF) systems and Systems-on-a-Chip for high performance sensing, communication and processing systems for future military requirements.

(U) Program Plans:
- Apply 3D design tools to test structure.
- Fabricate and test structures.
- Verify models against data.

	FY 2005	FY 2006	FY 2007
Multiple Optical Non-Redundant Aperture Generalized Sensors (MONTAGE)	5.454	4.070	4.248

(U) The MONTAGE program will implement a revolutionary change in the design principles for imaging sensor systems, enabling radical transformation of the form, fit, and function of these systems for a wide variety of high-value DoD applications. Significant improvements in the performance, affordability, and deployability of imaging sensor systems will be obtained through rational co-design and joint optimization of the imaging optics, the photo sensor array and the post-processing algorithms. By reaching well beyond conventional designs, MONTAGE sensors will realize optimal distribution of information handling functions between analog optics and digital post-detection processing.

(U) Specific demonstrations include reduction of the depth/thickness of an imaging sensor by an order of magnitude without compromising its light gathering ability or resolution. This dramatic reduction in thickness will then allow the imaging sensors to be deployed conformally around a curved surface of a platform (e.g., UAV, tank, or helmet). Furthermore, the flexibility generated by the incorporation of post-processing in the image formation will allow variable resolution image formation, which in turn reduces the data load for subsequent image exploitation and communication systems. Advanced post-processing algorithms will support video operation at frame rates in excess of 10 frames per second using standard computing platforms.

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(U) Program Plans:

- Develop novel optical designs allowing depth reduction by 10X.
- Concurrent with optics design, develop sensor array design and post-processing algorithms to realize signal-to-noise ratio and resolution of comparable optical aperture.
- Demonstrate ability to allocate highest spatial resolution to specified regions of interest in the image while maintaining medium resolution elsewhere.
- Develop architectures for surpassing detector size-limited resolution and potentially exceed optically limited resolution.
- Demonstrate operation of a thin imaging system deployed on a curved surface.
- Demonstrate real time performance of thin imaging systems in representative DoD applications with performance evaluated using application-specific metrics for image quality, sensor cost, power consumption, mechanical properties.

	FY 2005	FY 2006	FY 2007
Polymorphous Computing Architecture (PCA)	30.206	11.392	2.802

(U) The Polymorphous Computing Architectures (PCA) program is developing a revolutionary approach to the implementation of embedded computing systems to support reactive multi-mission, multi-sensor, and in-flight retargetable missions. This revolutionary approach will also reduce payload adaptation, optimization and verification processes from years to minutes. Current DoD embedded computing systems can be characterized as static in nature, relying on hardware-driven, heterogeneous point-solutions that represent static architectures and software optimizations. The program breaks the current development approach of hardware first and software last by moving beyond conventional silicon to flexible polymorphous computing systems. The key efforts of this revolutionary step forward in embedded computing systems are: (1) define critical reactive computing requirements and critical micro-architectural features; (2) explore, develop and prototype reactive polymorphous computing concepts; (3) explore, develop and prototype multi-dimensional verification and validation techniques for dynamic reactive missions; (4) provide early experimental testbeds and prototype polymorphous computing systems; and (5) extend PCA to enable early commercial product development and transition to the DoD and intelligence communities. The most promising PCA architectures, which include eXtended Tera-op Reliable Intelligently Adaptive Processing System (TRIPS) and eXtended MOrphable Networked microARCHitecture (MONARCH), are being further developed for transition to specific DoD and intelligence platforms. The result will be a new generation of on-board, embedded computing

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processing capability that will be mission and technology agnostic yet highly optimizable for each new mission scenario. This processing capability will provide tactical and strategic mission tempo opportunities as well as technical upgradeability over the life of the computing system. Based on an average of four major upgrades over a 30-year period, significant savings of up to 45 percent in development and deployment costs may be achieved over the life of a typical DoD embedded computing system.

(U) Program Plans:
- Develop multi-dimensional reactive computing optimization, verification techniques.
- Model, simulate and characterize complete candidate polymorphic computing systems including hardware elements, morphware, run-time systems and tools.
- Perform early small scale proof-of-concept testing, integration and evaluation of early polymorphic computing architecture prototypes.
- Demonstrate and quantify the potential of full up polymorphic computing architecture systems for the DoD and their complementary commercial viability.
- Select, develop, and perform a DoD risk reduction effort for a multi-mission application.
- Set the stage for technology transition to commercial and defense contractor communities in support of DoD applications.
- Perform early commercial product development and transition to the DoD and intelligence on-board embedded processing communities.

	FY 2005	FY 2006	FY 2007
Vertically Interconnected Sensor Arrays (VISA)	8.526	3.358	2.000

(U) The Vertically Interconnected Sensor Arrays (VISA) program will develop and demonstrate vertically interconnected, focal plane array (FPA) read-out technology capable of more than 20-bits of dynamic range, enabling significant advances in the functionality of infrared systems. The extremely high dynamic range will be accomplished by novel multilayer read-out circuits. These circuits will enable imaging at more than 20-bits of dynamic range, whereas the current state of the art is over an order of magnitude lower. Adaptive read-out circuits will be vertically connected to individual detectors in either monochromatic or stacked multicolor 2D staring arrays. The ability to bring signal directly from the

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detectors to the read-outs (i.e., vertical interconnection) without first going through row-column multiplexers will allow for high frame rates concurrently with high resolution images. A companion application-oriented program is funded in 6.3 (PE 0603739E).

(U) Program Plans:
- Develop a wafer stacking process incorporating high-density vias and design novel circuits that enable high frame rates, counter-measure hardening and adaptive signal processing functions on a concept test chip.
- Demonstrate a high dynamic range Analog/Digital VISA technology based sensor designed with advanced high performance circuit architecture implemented in stacked semiconductor process with high-density interconnections.
- Determine the best bands for improving the detection of objects in varying degrees of fog.

	FY 2005	FY 2006	FY 2007
CAD-QT (Cognitively Augumented Design for Quantum Technology)	0.000	1.902	2.000

(U) Develop and demonstrate revolutionary robust optimization-based methodology for the design of electronic and photonic devices whose novel functional capabilities derive from operation within the quantum regime. This program will transform the device designer’s art from its current intuition-based ad-hoc exploitation of quantum effects, which provides at best incremental advances in suboptimal devices. CAD-QT will replace this with computational design tools amplifying the designer’s experience and capability for systematic exploration of complex multi-physics systems. Use of these tools is expected to dramatically reduce the time and expense required to create practical devices and systems which optimally harness quantum effects to obtain desired function.

(U) Program Plans:
- Validate CAD-QT system by employing it to design optoelectronic modulator devices performing significantly beyond the current state of the art.
- Investigate the exploitation of new fields of nanophotonics and plasmonics, in which metal nanostructures convert electromagnetic radiation into charge density waves.

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	FY 2005	FY 2006	FY 2007
Direct Analog To Target ID - Non-Linear Math for Mixed Signal Microsystems	4.720	0.792	0.000

(U) The principal goal of this program is to demonstrate a significant linearity enhancement capability based upon a digital signal processing approach, implemented in a high performance, very large scale integration (VLSI) chip, that will enable wideband high-dynamic range sensor systems to be developed in a cost effective manner.

(U) Program Plans:

- Develop broadly applicable methodologies for exploiting novel encoding strategies, closed loop adaptive equalization, integration of sensing and processing, and application-specific knowledge in order to provide revolutionary advances in information conversion.
- Explore novel architectures leveraging intelligent pre-processing based upon space, time, and mathematical transformations of analog measurements and employing cooperative integration of analog and digital processing to obtain required system level performance.
- Work with new classes of quantization devices based on novel "error correcting" representations of numbers, such as beta encoders, phase encoders, geometric invariants.

	FY 2005	FY 2006	FY 2007
Processing Algrorithms with Co-design of Electronics (PACE)	0.000	0.000	4.000

(U) The Processing Algorithms with Co-design of Electronics (PACE) program seeks to develop the capability of rapid implementation of novel, high performance signal processing methodologies on readily available integrated circuit platforms. The PACE program will use an interdisciplinary treatment of areas usually examined in isolation, combining military signal processing applications with a rigorous treatment of advanced algorithms and integrated circuit design. By treating both hardware and algorithm optimization/exploitation in a unified way, processing performance can be exponentially increased and design time can be decreased by orders of magnitude compared to traditional implementations. This is accomplished by the development of automated exploration design tools for optimizing over a broad range of algorithmic options and

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circuit implementations that exceed the capabilities of human designers. Optimization criteria across the software and hardware include data representations, operations on the data, available hardware resources, on-chip and off-chip latencies, bandwidth and power. This approach is intended to be applicable to a variety of platforms as diverse as heterogeneous reconfigurable architectures, such as the state-of-the-art Field Programmable Gate Array (FPGA)s, or standard cell/structured Application Specific Integrated Circuits (ASIC)s. Recent advances in tractable robust optimization methodologies provide an essential enabler for practical realization of this vision.

(U) Program Plans:

- Establish algorithm classifications for critical military signal processing applications.
- Develop fast robust multi-objective function optimization methodologies.
- Develop fast simulation techniques for determining performance of those algorithms on the target IC fabric.

- Design of a system for choosing the optimal algorithm implantation given hardware and mission constraints.
- Create circuit tools that work with algorithm optimization engine for rapid IC implementation.

	FY 2005	FY 2006	FY 2007
NanoElectronics Defense and Security Initiative	1.500	0.000	0.000

(U) Program Plans:

- Developed cryo-electronic components for use in large military power systems. The initial focus was on Navy Ship Power Conversion.

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	FY 2005	FY 2006	FY 2007
Nanoscale Organic Spintronics	1.396	0.000	0.000

(U) Program Plans:
- Synthesized and characterized organic compounds for solid state devices using electronic spins and construct solid state devices from 2 and 3 qubit molecular systems.

	FY 2005	FY 2006	FY 2007
Center for Optoelectronics and Optical Communications	5.000	0.000	0.000

(U) The Center for Optoelectronics and Optical Communications program investigated advances in optical communications.

(U) Program Plans:
- Continued optoelectronic and optical communications development.

	FY 2005	FY 2006	FY 2007
Fabrication of 3D Structures/Characterization, Reliability, & Application	1.800	0.000	0.000

(U) The goal of the Fabrication of Three Dimensional Structures program was to investigate multi-chip module technology.

(U) Program Plans:
- Continued the development of key technologies behind a packaging concept that used a stacked multi-chip module approach to reduce interconnect length and increase physical connectivity between layers of electronics.

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	FY 2005	FY 2006	FY 2007
Testing & Evaluation of Advanced Composites	1.400	0.000	0.000

(U) This program initiated development of testing and evaluation processes for advanced composite materials.

	FY 2005	FY 2006	FY 2007
National Secure Foundry Initiative (SAFFE)	0.000	1.200	0.000

(U) The Secure Advanced Electronics Fabrication Facility for Electronics (SAEFF) aims to support and develop nanoelectronics innovations in support of homeland security and national defense applications, with target products ranging from power electronics systems, advanced superconductors, integrated “nanochip” solutions for lithography, 3-D integration, device modeling and simulation, and metrology applications.

	FY 2005	FY 2006	FY 2007
Semiconductor Nanoelectronics Research	0.000	0.500	0.000

(U) Scaling down of semiconductor device feature sizes has led to advanced electronic components and new capabilities for signal and data processing. This program is pursuing research concepts for shrinking semiconductor devices to the nanoscale and exploring applications to integrated microsystems.

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

	FY 2005	FY 2006	FY 2007
Previous President's Budget	261.406	241.736	249.453
Current Budget	254.514	239.959	246.978
Total Adjustments	-6.892	-1.777	-2.475
Congressional program reductions	-0.201	-3.477	
Congressional increases	0.000	1.700	
Reprogrammings	0.000		
SBIR/STTR transfer	-6.691		

(U) Change Summary Explanation:

FY 2005	The decrease reflects the SBIR/STTR transfer, the DOE transfer directed by P.L. 108-447 offset by an increase to realign the congressional add for Gelled Fuels and Oxidizers from OSD to DARPA for proper execution.
FY 2006	The decrease is due to undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission offset by congressional adds to SAFFE and Semiconductor Nanoelectronics Research.
FY 2007	Decrease reflects minor shifts in program pricing and phasing.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	66.919	54.594	115.829	202.587	250.823	250.923	253.923
Advanced Aerospace Systems AIR-01	66.919	54.594	115.829	202.587	250.823	250.923	253.923

(U) Mission Description:

(U) The Advanced Aerospace Systems program element is budgeted in the Advanced Technology Budget Activity because it addresses high payoff opportunities to dramatically reduce costs associated with advanced aeronautical systems and provide revolutionary new system capabilities for satisfying current and projected military mission requirements. Research and development of integrated system concepts, as well as enabling vehicle subsystems will be conducted. Studies conducted under this project include examination and evaluation of emerging aerospace threats, technologies, concepts, and applications for missiles, munitions, and vehicle systems.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
A160	9.000	7.000	10.500

(U) The A160 program will exploit a hingeless, rigid rotor concept operating at the optimum rotational speed to produce a vertical take-off and landing (VTOL) unmanned air vehicle (UAV) with 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 (2,500 nm) and/or endurance (24-32 hours). Detailed design, fabrication and testing of this vehicle is being conducted to establish its performance, reliability, and maintainability. The A160 concept is being evaluated for surveillance and targeting, communications and data relay, crew recovery, resupply of forces in the field, and special operations missions in support of Army, Navy, Marine Corps, and other agency needs. The program will also conduct development tests of heavy fuel engine technology in support of, and in coordination with, other DARPA programs that are developing highly efficient heavy fuel engine technologies to further advance current range and endurance projections as well as improve operational reliability and logistics

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compatibility. DARPA established an MOA with the Army for this program in April 2003. The A160 program will transition to the Army after completion of this Phase.

(U) Program Plans:
- Continue ground and flight test of A160 vehicles.
- Perform conceptual design and trade studies of A160 variants for a variety of mission roles, including study of technology risk reduction, architecture, survivability, and command and control.
- Develop new main rotor gearboxes for diesel and turboshaft engines.
- Integrate new advanced lightweight diesel engine on prototype A005.
- Integrate Pratt & Whitney 207 engines on A006 and A008.

	FY 2005	FY 2006	FY 2007
Advanced Aeronautics Demonstration	13.833	14.100	19.800

(U) The Advanced Aeronautics Demonstration program will develop novel aircraft concepts to enable the Services to perform wide-ranging and mixed missions outside the current flight envelope using advanced propulsion and aerodynamic technologies. The program consists of two primary projects, the Canard Rotor/Wing (CRW) and Heliplane.

(U) The Army, Navy, Air Force, Marine Corps and Special Operations Command Forces have a need for affordable, survivable, vertical take-off and landing (VTOL) air vehicles to support dispersed units. CRW aircraft offer the potential for a high-speed, rapid response capability from a VTOL air vehicle with significant range and stealth improvements as compared to other VTOL concepts. Design, fabrication, ground and flight test of a scaled vehicle demonstrator will validate the 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. Following demonstration of the small scale vehicle, the program will proceed with design, development and demonstration of more operationally representative vehicles including manned aircraft.

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(U) The Heliplane program will design, develop and flight test an air vehicle that combines the VTOL and low disk loading characteristics of a helicopter with the speed and efficiency characteristics of a fixed wing aircraft. The Heliplane demonstrator aircraft will be tailored to a Combat Search and Resuce (CSAR) mission with a 400 mph cruise speed, a 1000 lb payload, and an unrefueled range of 1000 miles. The Heliplane program will conduct a combination of analysis and experiments to develop and demonstrate key enabling technologies. Once key enabling technologies have been demonstrated, a preliminary and detailed design of the Heliplane system will be completed, a full scale test of the rotor system will be conducted, and a Heliplane demonstrator will be fabricated and flight tested.

(U) Program Plans:
- Complete CRW demonstrator flight tests.
- Continue design studies of follow-on CRW manned and unmanned vehicles.
- Perform Heliplane system trade studies and develop conceptual design.
- Develop and conduct risk-reduction demonstrations of key Heliplane technologies and components.
- Complete preliminary and detailed design of Heliplane demonstrator.
- Fabricate Heliplane demonstrator aircraft.
- Conduct flight tests to validate Heliplane performance.

	FY 2005	FY 2006	FY 2007
Oblique Flying Wing (OFW)	0.000	7.028	13.500

(U) The Oblique Wing aircraft is a flying wing, which flies with variable sweep to improve high speed characteristics. A supersonic, variable sweep oblique flying wing would be efficient in both high speed cruise and low speed loiter, would be compatible with survivability requirements, and would have a structurally efficient airframe. Possible missions that would take advantage of the combination of high and low speed performance could include: penetrating intelligence, surveillance, and reconnaissance; long range strike, hunter/killer and multimission aircraft. A supersonic aircraft capable of extremely long loiter times would have a revolutionary impact on the battlefield, necessitating fewer combat aircraft and fewer tankers to accomplish mission objectives. The goal of the Oblique Flying Wing (OFW) program is to expand the design space for future aircraft concepts, particularly for those missions that demand both supersonic speed and long endurance. The potential for a unique

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combination of excellent high speed and low speed performance would enable rapid deployment and long loiter time, for example, in surveillance or combat air patrol (CAP) roles. The OFW program will integrate technologies such as advanced controls to develop and fly one or more scaled demonstrator vehicles. The program will also identify key design requirements for the objective system, allowing the services to evaluate the technology for implementation in future operational systems. This effort was previously budgeted in this project under the Advanced Aeronautics Demonstration program.

(U) Program Plans:
- Develop oblique wing concept design.
- Define, develop and demonstrate key oblique wing component technologies.
- Begin system design for an objective oblique wing system and a flight demonstrator.

	FY 2005	FY 2006	FY 2007
Cormorant Unmanned Air Vehicle (UAV)	6.984	9.600	14.600

(U) The Cormorant Unmanned Air Vehicle (UAV) program will examine the feasibility of a UAV that may be deployed from the sea without carrier support. The program will explore concepts that launch from both the sea surface and submarines. Technical challenges include aircraft structural integrity and water tightness at submarine launch depths and on the surface, aircraft dynamics at the air/sea interface, engine technology to survive periodic immersion in salt water, and advanced composite materials development to withstand sea-surface operations. The Cormorant UAV is envisioned to provide close air support for vessels such as the Littoral Combat ship (LCS) and SSGN. Pending the outcome of demonstration results, transition of the Cormorant UAV to the Navy is planned after the completion of Phase III in FY 2010.

(U) Program Plans:
- Initiate feasibility studies; conduct modeling and simulation vehicle behaviors in the air/sea interface.
- Explore novel composite materials.
- Perform concept design studies.
- Perform engine quick start demonstration and engine concept development.

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- Perform risk reduction experiments for materials and subsystems including full scale end-to-end splashdown to docking demonstration.

	FY 2005	FY 2006	FY 2007
Heavy Fuel Engine for A160	6.687	6.612	10.729

(U) The Heavy Fuel Engine for the A160 program will develop and demonstrate a heavy-fuel, lightweight, and efficient engine for the A160 air vehicle. In the future, heavy fuel (diesel or JP-8) will be the only logistic fuel for the battlefield. Conventional heavy-fuel engines are too heavy for air vehicles and, at the desired size, not efficient enough. Innovative and advanced diesel engine designs are being developed to achieve both efficiency and a significant reduction in weight. The engines will enable the A160 to achieve maximum range and endurance while operating on diesel fuel. Detailed design, fabrication, and testing is being conducted to assess engine performance and reliability. The A160 Engine Development technology is planned for transition to the Army at the conclusion of Phase III, which is anticipated to be completed in 2007.

(U) Program Plans:
- Complete prototype engine performance and endurance testing.
- Perform engine design optimization based on lessons learned from build and test.
- Demonstrate performance and reliability of optimized engines at 38% efficiency, a power to weight ratio of 0.9hp/lb, and producing 450 hp at 15,000 ft.

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	FY 2005	FY 2006	FY 2007
Critical Munition Capability	6.500	7.000	8.000

(U) The Critical Munition Capability program consists of four efforts: HyperJAM (Hypersonic Joint Attack Munition), MAULLM (Multi-target Autonomous Loitering Littoral Munition), BEDLAM (Battlefield Electronically Disruptive Loitering Attack Missile), and DIME (Deep Interdiction with Multiple Engagements). The goal of each of these efforts is to provide the warfighter with a range of weapons that enable effective, precise, responsive, and decisive disruption to enemy forces.

(U) HyperJAM provides the capability to deliver GPS precision guided weapons to high value, well defended, and relocatable targets with range capability in excess of 400 nm. HyperJAM uses conventional rocket technology (black brandt rocket) integrated with a modified aerodynamically enhanced Joint Direct Attack Munition (JDAM) high speed nosecone to deliver MK84 munitions to precise locations. Utilization of a zoom maneuver from a high performance aircraft (F-16, F/A-18) allows delivery of an air-to-surface weapon on a ballistic trajectory that greatly enhances its range capability with the same lethality/accuracy.

(U) MAULLM will develop concepts and technologies for a containerized, platform-independent multi-mission weapon concept that will provide rapid response and lethality in packages with significantly lower missile unit cost, decreased logistical support and lower life-cycle costs, while increasing flexibility compared to current Naval gun and missile systems. MAULLM will address current Naval threats such as massed, swarming suicide attack boats, and will significantly enhance operations ashore by providing a long-loiter, on-call weapon capable of engaging multiple (~10) individual targets.

(U) BEDLAM will develop conceptsand technologies for detection, exploitation, and disruption of a wide variety of enemy electronic emissions and will integrate them into a mission module suitable for use on small loitering missiles to establish patterns or meetings with other emitters to aid in intelligence and targeting.

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(U) DIME will develop weapons capable of a wide variety of interdiction and persistent control missions in the most difficult environments with minimal supervision after initial tasking. The program will re-examine the trade-space between missiles and aircraft, with the objective of the operational utility of aircraft and UAVs with the support requirements, acquisition characteristics, and attritability of munitions. All aspects of the weapon system will be considered, and technology development will be considered in those found to be mission drivers, including sensors, autonomous operation, command and control, warheads, submunitions, airframe, propulsion, and concept of operations.

(U) Program Plans:

- HyperJam
  - Completed simulation studies to determine range capability and control requirements for potential Army, Navy and Air Force customers.
  - Develop system level requirements for air and gun delivered munitions.
  - Develop integrated missile/munition concepts with greater range and lethality.
  - Initiate preliminary system design.

- MAULLM
  - Develop and demonstrate critical technologies.Conduct preliminary design studies.
  - Evaluate communication and command and control technologies and select best option(s).

- BEDLAM
  - Conduct initial experiments and modeling to determine system requirements.
  - Complete preliminary design study.

- DIME
  - Develop mission concepts and technical requirements studies.
  - Define trades between alternative system concepts with modeling and experiments.
  - Complete preliminary designs.
  - Complete technology risk reduction development.
  - Develop and demonstrate completed system.

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	FY 2005	FY 2006	FY 2007
Advanced Aerospace System Concepts	3.310	3.254	4.900

(U) Studies conducted under this project examine and evaluate emerging aerospace technologies and system concepts for applicability to military use. This includes the degree and scope of potential impact/improvements to military operations, mission utility, and warfighter capability. Studies are also conducted to analyze emerging aerospace threats along with possible methods and technologies to counter them. The feasibility of achieving potential improvements, in terms of resources, schedule, and technological risk, is also evaluated. The results from these studies are used, in part, to formulate future programs or refocus ongoing work. Topics of consideration include: methods of defeating enemy anti-aircraft attacks; methods to intercept and defeat enemy unmanned air vehicles (UAVs); munition technologies to increase precision, range, endurance and lethality of weapons for a variety of mission sets; novel launch systems; and air vehicle control, power, propulsion, materials, and architectures.

(U) Program Plans:
- Perform studies of candidate technologies and develop system concepts.
- Conduct modeling and simulation of system architectures and scenarios.
- Conduct enabling technology and sub-system feasibility experiments.

	FY 2005	FY 2006	FY 2007
Long Gun	6.185	0.000	0.000

(U) The Long Gun program evaluated and developed a re-useable, long endurance, low cost, joint, unmanned/armed air vehicle combined with a tri-mode long wave infrared/near infrared/visible (LWIR/NIR/VIS) sensor with laser spot targeting. The program utilized a ducted fan propulsion system. This program was last funded in FY 2005, and will be completed in FY 2006 at the conclusion of Phase I.

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(U) Program Plans:

- Modified existing Affordable Weapon System airframe as basis for missile design.
- Replaced engine with ducted fan, rotary engine operated with heavy fuel.
- Developed and integrated tri-mode sensor/seeker with laser spot recognition for targeting.
- Developed avionics package to support long-endurance flight.
- Conducted inert flight tests and demonstrated long endurance operation.

	FY 2005	FY 2006	FY 2007
Global Range Transatmospheric Vehicle	0.000	0.000	5.300

(U) The Global Range Transatmospheric Vehicle program will develop a turbine-based combined cycle propulsion system consistent with the flight envelope of the Falcon (PE 0603287E/SPC-01) Hypersonic Cruise Vehicle concept, but subscale and of limited operational durability. To accomplish this objective, the program will further mature, integrate and flight-demonstrate propulsion technologies developed by the High Speed / Hypersonic Reusable Demonstration program (budgeted under PE 0602702E, Project TT-07) and the Falcon program (PE 0603287E). A scramjet engine flow path design, consistent with the Falcon Hypersonic Cruise Vehicle concept, will be matured to flight readiness. This flow path will then be integrated with a Mach 4, expendable turbine engine developed under the first of these previously mentioned programs to conduct a combined cycle engine ground demonstration. Successful accomplishment of the ground demonstration will lead to a flight demonstration of these systems in both low speed (turbojet) and high speed (scramjet) flight regimes. The program will also conduct studies and analysis of reusable materials technologies and thermal management strategies for these propulsion systems to determine the utility and potential applicability of those technologies to the end system. Accomplishment of these objectives will enable a future large scale hypersonic cruise X-vehicle development and demonstration program.

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(U) Program Plans:
- Mature scramjet flow path.
- Integrate turbine and scramjet engines.
- Conduct ground testing of combined cycle engine.
- Conduct a flight-test demonstration.

	FY 2005	FY 2006	FY 2007
Dual Mode Small Gunship	0.000	0.000	6.000

(U) The objective of the Dual Mode Small Gunship project is to build, test and fly a low-cost small aircraft, configured with sensors, weapons and special equipment, that is controlled either remotely or by a crew onboard. The vehicle will demonstrate persistent, sustained gunship and strike mission capabilities with troops on the ground directly commanding the aircraft's weapons and sensors. The gunship will give the ground warfighter particular advantage in urban environments where it will operate with high availability, fast response, precision strike and low collateral damage. The ability to have a pilot on-board will allow for easy deployment to theater and safe operation over populated areas by allowing the pilot to interface with the air traffic control infrastructure rather than the current, cumbersome method of deploying large UAVs. The plan to "unman" an existing aircraft also minimizes development costs. The Dual Mode Small Gunship is expected to have low development and procurement costs, high endurance and range, a large payload, and high dash speeds with a day/night adverse weather capability. Potential customers include the Army, SOCOM, Marines, and AFSOC.

(U) Program Plans:
- Modify an existing low cost aircraft for use as an "optionally piloted" aircraft, with weapons systems and sensors.
- Demonstrate ability to control the aircraft, its weapons and sensors from the ground.

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	FY 2005	FY 2006	FY 2007
Seaplane Unmanned Air Vehicle (UAV)	0.000	0.000	5.500

(U) This program will develop an unmanned amphibious seaplane concept that could provide the Navy and Marine Corps with the capability to take-off and land in the water at very high sea states (up to sea state 5). It will be able to "rest" in a sea loiter mode for long periods of time and wait for further commands, extending quiescent endurance time to days until an action is required. It will also be able to fly back to any friendly ship and refuel. Potential missions include intelligence, surveillance, reconnaissance and targeting (ISRT), communications relay, electronic warfare, unmanned undersea vehicle (UUV) delivery and recovery, and anti-submarine warfare (ASW). Other potential customers could include the Coast Guard and SOCOM. The seaplane UAV will also be able to take-off and land on rivers and lakes, facilitating surveillance and other missions over land operations.

(U) Program Plans:
- Conduct initial feasibility studies.
- Conduct subsystem risk analysis and laboratory tests.
- Initiate preliminary design.

	FY 2005	FY 2006	FY 2007
Heavy Lift	0.000	0.000	6.000

(U) Heavy Lift Short Take Off and Landing/Verticle Take Off and Landing (STOL/VTOL) aircraft are an essential part of the future ground force. The objective of this program is to develop and demonstrate technologies that would lead to novel STOL/VTOL air vehicle concepts and designs. An objective VTOL aircraft would be able to lift a 20-ton payload and carry it forward at speeds of 200+ knots with a tactical radius of 400 or more miles. Such a vehicle would be optionally-manned. Technology advances may include advanced rotors, propellers, hybrid-mode engines, and advanced composite airframes. Transition partners for the Heavy Lift program will be sought in Army, Marine Corps, Special Operations Command, and Navy.

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(U) Program Plans:
- Perform trade studies and modeling and simulation.
- Develop and test enabling technologies/subsystems.
- Conduct preliminary design.

	FY 2005	FY 2006	FY 2007
Close Air Support Technology for Loitering Engagement (CASTLE)	0.000	0.000	5.000

(U) The Close Air Support Technology for Loitering Engagement (CASTLE) program will develop alternatives to current, manned systems and explore approaches to provide persistent on-demand overhead fire support with gun-ship like precision, tailored lethal effectiveness and unit directed responsive command and control. Key technologies to be analyzed, developed and integrated under CASTLE include 1) affordable, survivable, and persistent unmanned aircraft , 2) weapons consistent with man-on-the loop close air support application, such as auto-loading EM guns, directed energy weapons, vertical launch missiles, or deep magazine traditional guns and precision bombs, 3) sensors for targeting and designation and 4) an adaptive command and control system to permit small unit request, coordination, and direction of supporting fires.

(U) Program Plans:
- Evaluate candidate technologies for CASTLE.
- Conduct initial concept tradeoff for preliminary CASTLE system designs.
- Perform modeling and simulation of alternative candidate air system architectures to assess effectiveness of alternative CASTLE approaches.
- Complete preliminary design of air vehicle design concept and development.
- Perform CASTLE technology risk reduction experiments and demonstrations.

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	FY 2005	FY 2006	FY 2007
Aircraft Self Protection (ASP)	0.000	0.000	6.000

(U) The Aircraft Self Protection (ASP) program will explore the active protection of slow moving, high altitude aircraft systems with guided missiles or high energy laser weapons as an alternative/complement to passive defense by signature control. Today such aircraft rely on stealth technology to avoid detection and engagement by long range surface to air missile threats. In the future, the unique advantage enjoyed by the United States may be eroded by technological advances, and stealthy aircraft often give up their advantage in detectibility when they utilize active radar and laser sensors in the conduct of their mission. An active aircraft self-defense system could relax the design constraints imposed by signature control, allowing a greater range of platform capabilities. Because lasers provide “speed-of-light” response and a deep magazine, we will examine their suitability relative to the more conventional missile based solutions. The ASP program will evaluate both pod-mounted and fully integrated system concepts and will develop and demonstrate missile detection, threat tracking, engagement, and defeat at a safe range.

(U) Program Plans:

- Perform ASP system tradeoff analysis, resulting in system size, weight, power and effectiveness criteria.
- Evaluate alternative high energy laser designs and missile or projectile technology for ASP applications.
- Demonstrate integration of missile warning and tracking capabilities with lightweight beam director technology against incoming missile threats.
- Select initial ASP design concept and perform development to preliminary design review.

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	FY 2005	FY 2006	FY 2007
Unmanned Combat Armed Rotorcraft (UCAR)	10.000	0.000	0.000

(U) The goal of the Unmanned Combat Armed Rotorcraft (UCAR) program was to design, develop, integrate and demonstrate the enabling technologies and system capabilities required to perform armed reconnaissance and attack missions within the Army's Future Force system-of-systems environment. The enabling technologies were survivability, autonomous operations, command and control, and targeting/weapons delivery. A highly survivable UCAR system would be able to prosecute enemy high value targets with relative impunity without placing a pilot in harm's way. UCAR's autonomous capabilities could have enabled effective teaming with manned systems and could have eliminated the requirement for a dedicated ground control station. The UCAR capabilities could have provided the Future Force with the mobility, responsiveness, lethality, survivability, and sustainability required to ensure mission success. Specific objectives of the UCAR program included: development and demonstration of an effective, low total ownership cost design for the system; an air and ground-based command and control architecture for UCAR operations that did not require a dedicated ground control station; autonomous multi-ship cooperation and collaboration; autonomous low altitude flight; and system survivability. In recognition of the Army's decision to terminate their support of the program, DARPA's efforts were completed at the end of Phase II.

(U) Program Plans:

- Completed system trades, effectiveness, and affordability analyses through modeling and simulation.

	FY 2005	FY 2006	FY 2007
Modular Blended Wing Body Multi-Role Aircraft (MBWB MRA)	4.420	0.000	0.000

(U) The goal of the MBWB MRA effort was to develop and demonstrate a system that could efficiently and affordably meet the Joint Service needs for a bomber, tanker, and transport. The MBWB MRA would have been reconfigurable on the flight line to a bomber, tanker, or transport in less than 24 hours. Commercial derivatives of the MBWB MRA would have carried freight at a cost per air ton mile that is 20-40% below that of existing aircraft.

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(U) Program Plans:

– Performed system and conceptual design studies.
– Explored various mission capabilities and completed military needs and utility analyses.

(U) Program Change Summary: *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	71.420	75.866	111.029
Current Budget	66.919	54.594	115.829
Total Adjustments	-4.501	-21.272	4.800
Congressional program reductions	-0.063	-21.272	
Congressional increases	0.000		
Reprogrammings	-2.354		
SBIR/STTR transfer	-2.084		

(U) Change Summary Explanation:

FY 2005	Decrease reflects DOE transfer directed by P.L. 108-447 and the SBIR/STTR transfer.
FY 2006	Decrease reflects the congressional reductions to HABIT, Long Gun, undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Increase reflects introductions of several new aircraft concepts and the Global Range Transatmospheric Vehicle, offset by elimination of funding for HABIT and Walrus, in keeping with congressional intent.

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(U) Other Program Funding Summary Cost:

A160	FY 2005	FY 2006	FY 2007
Army S&T, Phase I	15.000	10.000	15.000
Army S&T, Phase II	0.000	9.190	18.740

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	217.004	216.357	254.913	294.648	317.360	328.943	334.598
Space Programs and Technology SPC-01	217.004	216.357	254.913	294.648	317.360	328.943	334.598

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

(U) The Space Programs and Technology program element is budgeted in the Advanced Technology budget activity because it addresses high payoff opportunities to dramatically reduce costs associated with advanced space systems and provides revolutionary new system capabilities for satisfying current and projected military missions.

(U) A space force structure that is robust against attack represents a stabilizing deterrent against adversary attacks on space assets. In addition to the ability to detect and characterize potential attacks, robustness against attack is provided by proliferation of assets, ready access to space, the ability to neutralize man-made space environments, and a flexible infrastructure for maintaining the capabilities of on-orbit assets. Ready access to space allows the delivery of defensive systems and replenishment supplies to orbit. An infrastructure to service the mission spacecraft allows defensive actions to be taken without limiting mission lifetime. In addition, developing space access and spacecraft servicing technologies will lead to reduced ownership costs of space systems and new opportunities for introducing technologies for the exploitation of space. Systems development is also required to increase the interactivity of space systems, space-derived information and services with terrestrial users. Studies under this project include technologies and systems that will enable satellites and microsatellites to operate more effectively by increasing maneuverability, survivability, and situational awareness; enabling concepts include solar thermal propulsion, novel ion-thruster applications, payload isolation and pointing systems.

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(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Orbital Express Space Operations Architecture	46.599	37.271	31.711

(U) The goal of the Orbital Express Space Operations Architecture program is to validate the technical feasibility of robotic, autonomous on-orbit refueling and reconfiguration of satellites to support a broad range of future U.S. national security and commercial space programs. Refueling satellites will enable frequent maneuver to improve coverage, change arrival times to counter denial and deception and improve survivability, as well as extend satellite lifetime. Electronics upgrades on-orbit can provide regular performance improvements and dramatically reduce the time to deploy new technology on-orbit. The Orbital Express advanced technology demonstration will design, develop and test on-orbit a prototype servicing satellite (ASTRO) and a surrogate next generation serviceable satellite (NextSat). The elements of the Orbital Express demonstration, coordinated with Air Force Space Command and Air Force Space and Missile Command, will be tied together by non-proprietary satellite servicing interfaces (mechanical, electrical, etc.) that will facilitate the development of an industry wide on-orbit servicing infrastructure. NASA will apply the sensors and software developed for autonomous rendezvous and proximity operations to reduce risk for collaborative human-robotic operations in space for the NASA Exploration Initiative. Launch of the demonstration system is scheduled for September 2006 on the Air Force Space Test Program STP-1 mission.

(U) Program Plans:

- Develop and validate software for autonomous mission planning, rendezvous, proximity operations and docking.
- Design, fabricate, and test on-orbit robotic satellite servicing, including fuel and electronics transfer, deployment of and operations with a micro-satellite.
- Perform utility assessments of on-orbit servicing in conjunction with operational customers and plan for technology transition.

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	FY 2005	FY 2006	FY 2007
Space Surveillance Telescope	16.673	18.592	9.771

(U) The Space Surveillance Telescope program will develop and demonstrate an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability. The program will leverage recent advances in curved focal plane array sensor technology to enable an innovative telescope design that combines high detection sensitivity, short focal length, wide field of view and rapid step-and-settle to provide orders of magnitude improvements in space surveillance. This capability will enable ground-based detection of un-cued objects in space for purposes such as asteroid detection and other defense missions. The Air Force will participate in the DARPA funded development testing of SST and then take over operation of SST as a sensor in the Air Force Space Surveillance Network. An MOA has been established with Air Force Space Command for transition at the conclusion of Phase II that is anticipated to be completed by FY 2009.

(U) Program Plans:
- Develop, fabricate, and integrate a mosaic of curved focal plane arrays into a wide field–of-view detector system.
- Develop, test, and validate software for autonomous telescope operations and data reporting.
- Design and fabricate telescope enclosure and supporting infrastructure at White Sands Missile Range.
- Validate end-to-end telescope performance and surveillance operations.

	FY 2005	FY 2006	FY 2007
Innovative Space-Based Radar Antenna Technology (ISAT)	45.000	45.000	50.000

(U) The Innovative Space-Based Radar Antenna Technology (ISAT) effort will develop radically new enabling technologies and design methods for extremely large space-based radio frequency (RF) antenna technologies necessary for tactical-grade ground moving target indicator (GMTI) radar. Up to 300 meters long electronically scanned antenna (ESA) designs will be developed by leveraging major advances in novel materials (such as rigidized inflatables and shape memory polymers), packing techniques and ultra lightweight low-power density RF electronics.

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An antenna of this size enables a medium earth orbit (MEO) constellation that provides 24/7 true continuous coverage with 10 to 12 satellites (about 96 satellites at low earth orbit (LEO) would be required to provide the same level of coverage). The Innovative Space-Base Radar Antenna Technology (ISAT) also enables detection and tracking of all airborne targets. The ISAT program will retire the risk associated with two major technical obstacles: 1) the reliable and controllable deployment of a ~300 meter long electronically scanned antenna (ESA) with a linear compaction ratio of 100:1; and 2) the on-orbit calibration (particularly on transmit) and control of the ISAT antenna. Novel power generation and distribution systems will also be investigated. The program will conduct ground-based risk reduction experiments demonstrating the accuracy of the constitutive models for deployment and control of large antenna structures and will also develop concepts of operations, performance predictions and lifecycle cost models for the selected designs, as well as investigate the applicability of the technologies to other missions. These designs will be down selected to carry out a space-based experiment of the critical technologies. DARPA is establishing an MOA with the Air Force for this program. The ISAT technology is planned for transition to the Air Force at the conclusion of Phase IV, which is anticipated to be completed by FY 2010.

(U) Program Plans:

- Tested the mechanical and environmental properties of materials and structural components.
- Simulated metrology and calibration approaches for large space antenna structures.
- Initiated development of next-generation lightweight electronics, materials and deployment structures.
- Design of risk reduction demo experiment.
- Perform ground-based risk reduction experiments for packaging and deployment mechanisms and materials, including simulation of mechanical and thermal loads.
- Perform ground-based risk reduction experiments of the metrology and calibration approaches in preparation for on-orbit demonstration.
- Build and perform flight demonstration of prototype system.

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	FY 2005	FY 2006	FY 2007
Novel Satellite Communications	6.208	8.500	14.575

(U) The aim of the Novel Satellite Communications (NSC) program is the development of an advanced, affordable multi-user satellite communications (SATCOM) system that allows ground-based users with handheld radios to communicate with the satellite at high data rates, even when the users are close to multiple jammers and/or located in urban (i.e. severe multi-path) settings. This will be accomplished through advanced low-weight, highly compactable antennas and novel signal processing, communications and coding techniques. The NSC technology will transition to the U.S. Navy (SPAWAR) and U.S. Air Force (SMC) following the NSC demonstration in 2008.

(U) Program plans:
- Developed novel NSC system.
- Determined feasibility of novel concepts to enable robust communications in the presence of multiple nearby jammers.
- Develop signal processing, communications and coding techniques that fully exploit the novel concepts to provide a robust anti-jam capability in the presence of multiple nearby jammers.
- Carry out proof-of-concept demonstrations.

	FY 2005	FY 2006	FY 2007
Integrated Sensor is Structure (ISIS)	(11.000)	(18.000)	16.262

(U) The ISIS program is developing a sensor of unprecedented proportions that is fully integrated into a stratospheric airship that will address the nation's need for persistent wide-area surveillance, tracking, and engagement for hundreds of time-critical air and ground targets in urban and rural environments. ISIS is achieving radical sensor improvements by melding the next-generation technologies for enormous lightweight antenna apertures and high-energy density components into a highly-integrated lightweight multi-purpose airship structure - completely erasing the distinction between payload and platform. The ISIS concept includes 99% on-station 24/7/365 availability for Simultaneous Airborne Moving Target Indicator (AMTI) (600 kilometers) and Ground-Based Moving Target Indicator (GMTI) (300 kilometers) operation; 12+ months of

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autonomous unmanned flight; hundreds of wideband in-theater covert communications links; plus CONUS-based sensor analysis and operation. The ISIS technology is planned for transition to the Army's PEO-Air, Space and Missile Defense (ASMD), Air Force Joint Warfighter Space and the Missile Defense Agency at the conclusion of Phase IV which is anticipated to be completed by FY 2011. This program was formerly funded under PE 0603767E, Project SEN-01.

(U) Program Plans:
- Develop objective system concept designs enabling simultaneous AMTI and GMTI operation, one year logistics-free operation, 99% on-station availability, and high-bandwidth covert communications.
- Identify specific mass-reducing technologies for key radar, power, and airship components.
- Develop and demonstrate lightweight technologies for system integration (i.e. high-energy density batteries, electronic circuits on thin-film barrier materials, advanced multi-purpose airship hulls, and regenerative fuel technologies).
- Design and simulate new radar modes: tracking air and ground targets through the clutter notch; detection and response to rockets, artillery, and mortars (RAM); detection of dismounted enemy combatants; and “track-all-the-way” fire-control.
- Design, build and demonstrate a fully-operational scaled flight system demonstrating complete system integration over an extended period (~3 months).

	FY 2005	FY 2006	FY 2007
Ground Based Imaging (GBI)	0.000	0.000	2.200

(U) The Ground Based Imaging program will develop a capability for sub-meter resolution of non-rotating objects in geostationary orbit. The technology will use a very high power, millimeter wave (W-band) frequency illuminator and a very large, coherent sparse array receiver. The overriding technical obstacle is the integration of a very large (100s of kilometers) ground-based bi-static radar system with image processing capabilities that could produce results in a timely manner. This capability will augment existing radar imaging systems that rely on object motion to generate high resolution images.

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(U) Program Plans:
- Evaluate performance capabilities versus system design parameters and component technologies.
- Prove feasibility in sub-scale tests.
- Design, build, and test prototype for space object imaging.

	FY 2005	FY 2006	FY 2007
Deep View	14.420	11.920	10.250

(U) The Deep View program will develop a high-resolution radar imaging capability to characterize objects in earth orbit. A special emphasis will be placed on imaging small objects at orbits ranging from low earth orbit (LEO) to geo-stationary orbit (GEO). The system will be based upon a large aperture imaging radar system redesigned to operate at very high power over very broad bandwidth at W-band. Key technology development will focus on: (1) transmitters capable of providing the required power to image at deep-space ranges over full bandwidth; and (2) an antenna design that maintains the necessary form factor over a very large aperture. The capabilities emerging from this program will enable the classification of unknown objects, such as space debris, as well as the monitoring of the health and status of operational satellites. DARPA established an MOA with the Air Force for this program in August 2004. The Deep View technology is planned for transition to the Air Force at the conclusion of Phase III, which is anticipated to be completed by FY 2009.

(U) Program Plans:
- Fabricate additional gyro-twystron transmitter tubes.
- Perform transmitter power combiner experiments.
- Complete transmitter design and radar system design.
- Begin antenna replacement.
- Begin signal processing software development and testing.
- Integrate into a low-power configuration in FY 2008, providing LEO-only capability.
- Demonstrate LEO-GEO imaging capability using a full set of gyro-twystrons.

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	FY 2005	FY 2006	FY 2007
Responsive Access, Small Cargo, Affordable Launch (RASCAL)	2.500	0.000	0.000

(U) The goal of the Responsive Access, Small Cargo, Affordable Launch (RASCAL) program was to develop a low cost orbital insertion capability for micro-size satellite payloads. The concept consisted of a responsive, routine, small payload delivery system capable of providing flexible access to space using a combination of reusable and low cost expendable vehicle elements. Specifically, the RASCAL system concept included a reusable airplane-like first stage vehicle called the mass injection pre-compressor cooling (MIPPC) powered vehicle (MPV) and a second and third stage expendable rocket vehicle (ERV). The RASCAL demonstration objective was to place satellites and commodity payloads, between 50 and 130 kilograms in weight, into low earth orbit at any time, with a launch cost of less than $20,000 per kilogram. While the cost goal was commensurate with current large payload launch systems, it was estimated that the operational system, through production economies of scale, would have been more than a factor of three less than current capabilities for the dedicated micro payload size. Such a capability could enable cost effective use of on-orbit replacement and re-supply and provide a means for rapid launch of orbital assets for changing national security needs. The RASCAL program will not continue into Phase III. Planned testing and experiments to demonstrate the utility of the MIPCC propulsion augmentation technology were completed in 2005. The RASCAL program has been completed.

(U) Program Plans:

- Developed Contractor Life Cycle Cost Model (CLCC).
- Selected preferred system concept.
- Conducted early Risk Reduction testing of subsystems: J-85 and F-100 turbine engine testing with MIPCC for thrust augmentation, aircraft wind tunnel for stability, aircraft engine inlet wind tunnel testing, scaled static fires of hybrid motors, Guidance, Navigation & Control (GN&C) simulation, and Reaction Control System (RCS) firing.
- Completed prototype Mass Injection Pre-Compressor Cooling (MIPCC) manifold – engine testing.

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	FY 2005	FY 2006	FY 2007
Tactically Responsive Satellites (TRS)	2.924	0.000	0.000

(U) The TRS program developed next generation satellite systems capable of on-demand deployment. Existing satellite systems require extensive time to both integrate onto launch vehicles and checkout once on orbit. This timeline, currently on the order of months (at best), needs to be shortened to days or even hours. Examples of militarily significant tactical payloads include imaging, surveillance, reconnaissance (ISR), as well as tactical communications. Rapid replenishment of space assets in the event of pre-mature failure, or worse, is a major side benefit of TRS technology. Enabling technologies that played a role in the TRS program include next generation lightweight and highly compactable aperture technologies (RF, EO/IR, optical, etc.), novel rapid checkout microsat spacecraft designs, composite bus structures, and advanced lightweight electronics. The technologies transitioned to the newly formed Air Force Tactical Satellite (TACSAT) program at the end of FY 2005.

(U) Program Plans:
- Evaluated the feasibility of candidate TRS missions.
- Developed candidate designs for tactically responsive warfighter payloads.
- Developed and matured key enabling technologies.

	FY 2005	FY 2006	FY 2007
Falcon	12.500	35.600	51.500

(U) The Falcon program objectives are to develop and demonstrate hypersonic technologies that will enable prompt global reach missions. This capability is envisioned to entail a reusable Hypersonic Cruise Vehicle (HCV) capable of delivering 12,000 pounds of payload a distance of 9,000 nautical miles from CONUS in less than two hours. The technologies required by a HCV include high lift-to-drag technologies, high temperature materials, thermal protection systems, and guidance, navigation, and control. Leveraging technology developed under the Hypersonic Flight (HyFly) program, Falcon will address the implications of hypersonic flight and reusability using a series of hypersonic technology vehicles (HTVs) to incrementally demonstrate these required technologies in flight. In order to implement this flight test program in an affordable manner,

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Falcon will develop a low cost, responsive Small Launch Vehicle (SLV) that can be launched for $5M or less. In addition to hypersonic technology vehicles (HTV) sub-orbital launches, the SLV will be capable of launching small satellites into low earth and sun-synchronous orbits and will provide the nation a new, small payload access to space capability. Thus, the Falcon program addresses many high priority mission areas and applications such as global presence and space lift. DARPA established an MOA with the Air Force for this program in May 2003 and with NASA in October 2004. Falcon capabilities are planned for transition to the Air Force at the conclusion of Phase III, which is anticipated to be completed by FY 2010.

(U) Program Plans:

- Completed preliminary design for HTV-1 technology flight demonstration vehicle.
- Conducted wind tunnel test of HTV-1 aero configuration.
- Completed SLV preliminary designs.
- Conducted SLV scaled hybrid motor firings.
- Conducted SLV propulsion injector and ablative chamber firings.
- Conducted SLV first stage static firing.
- Conducted full scale size, subscale weight, air launch drop test.
- Conduct early launch demonstrating responsive operations.
- Conducted HTV-1 critical design review and purchased long lead items.
- Conduct multiple full scale size, full scale weight air launch drop tests.
- Conduct SLV full scale engine firings.
- Conduct critical design review of HTV-2 demonstration system, and initiate fabrication.
- Conduct critical design review of SLV, and initiate fabrication.
- Initiate preliminary design of the HTV-3 technology flight demonstration vehicle.
- Conduct HTV-1 flight demonstration.
- Conduct SLV flight demonstration.
- Conduct critical design review of HTV-3 demonstration system and initiate fabrication.
- Conduct flight testing of HTV-2 incorporating next generation hypersonic technologies.
- Conduct flight-testing of advanced reusable technologies for HCV.

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	FY 2005	FY 2006	FY 2007
Rapid On-Orbit Anomaly Surveillance and Tracking (ROAST)	6.000	2.000	0.000

(U) The goal of the Rapid On-Orbit Anomaly Surveillance and Tracking (ROAST) program is to develop technologies to enable low-cost, responsive spacecraft and capabilities, such as space situational awareness and blue force tracking. Key payload technologies include light-weight optics, adaptive focal plane array sensors, and efficient space-qualified receivers and processors. The program focuses on technologies that will enable a spacecraft deployment from a small launch vehicle and affordable enough to be launched on-demand to support dedicated tactical mission needs in the direct control of the warfighter.

(U) Program Plans:

- Evaluated light-weight, large area optics fabrication capabilities.
- Develop focal plane array, read out electronics, data processing algorithms.

	FY 2005	FY 2006	FY 2007
High Frequency Active Auroral Research Project (HAARP)	15.006	0.000	0.000

(U) The High Frequency Active Auroral Research Project (HAARP) developed new experimental research capabilities and conducted research programs to exploit emerging ionosphere and radio science technologies related to advanced defense applications. The FY 1990 Appropriation Act provided funds for the creation of HAARP, jointly managed by the Air Force Research Laboratory and the Office of Naval Research to exploit emerging ionosphere and high power radio technology for new military systems applications. Key to the current effort was the expansion of the experimental research facility that includes a 3.6 MW high-frequency transmitter and a variety of diagnostic instruments, to conduct investigations to characterize the physical processes that can be initiated and controlled in the ionosphere and space, via interactions with high power radio waves. Among these were: (1) the generation of extremely low frequency/very low frequency radio waves for submarine and other subsurface communication, and the reduction of charged particle populations in the radiation belts to ensure safe spacecraft systems operations; (2) the control of electron density gradients and the refractive properties in selected regions of the ionosphere to create radio wave propagation channels; and (3)

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the generation of optical and infrared emissions in space to calibrate space sensors. To date, the facility has been developed to include a suite of optical and radio diagnostics and an advanced, modern, high frequency transmitting array that has a radiated power of 960 kW, about one-third of the 3.6MW called for in the original concept and plan. The current high frequency transmitting array has proven to be extremely reliable and flexible, and has shown the feasibility of the overall concept. However, results to date have indicated that the advanced applications-related research activities and new military system concept demonstrations envisioned under the program require that the high frequency transmitting capability at the site be increased from the present 960 kW level to the originally planned 3.6 MW level. A study completed by an Air Force/Navy Panel also pointed to additional high-value functions that can potentially be accomplished with the a 3.6 MW capability, in particular, the exploration and refinement of scientific principles that could lead to the development and deployment of a system to provide protection for space-based assets from emergent asymmetric threats. DARPA established an MOA with the Air Force and Navy for this program in November 2002. The HAARP technology is transitioning to the Air Force and Navy in FY 2006.

(U) Program Plans:
- Completed the HAARP high frequency transmitting array at the HAARP Research Station, Gakona, AK.
- Prepared the existing HAARP facility in preparation for ionospheric testing.
- Conducted advanced ionosphere and radio science research and analysis of applications including space-based asset protection and phenomena related to its implementation.

	FY 2005	FY 2006	FY 2007
Sleight of HAND (SOH)	5.390	7.482	6.636

(U) This program will leverage technologies developed under the HAARP program, also budgeted under this project. The effects of High Altitude Nuclear Detonations (HAND) are catastrophic to satellites. HAND-generated charged particles are trapped for very long periods of time, oscillating between the earth’s north and south magnetic poles. This enhanced radiation environment would immediately degrade low earth orbiting (LEO) spacecraft capability and result in their destruction in a short period of time. The Sleight of HAND (SOH) program is a proof of concept demonstration of the technology and techniques to mitigate the HAND-enhanced trapped radiation. The goal of SOH is to accelerate the rate of decay of trapped radiation from the LEO environment by a factor of 10 over the natural rate of decay. In Phase 1, SOH will use a high

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power ground-based source of very low frequency (VLF) radiation propagating through the ionosphere to deflect the trapped radiation deep into the atmosphere. If the ground-based proof of concept shows VLF radiation remediation concepts are valid and cost-effective, a space-based demonstration that may lead to an operational capability will be pursued. If successful, follow-on programs to perform HAND produced radiation remediation will be pursued by the Air Force.

(U) Program Plans:
- Develop VLF propagation and radiation interaction/effects model.
- Construct and deploy an instrumented buoy to sense and report VLF signal strength and effects of VLF on trapped radiation.
- Utilize the HAARP facility to perform 1-hop experiments to anchor VLF propagation and interactions model.
- Perform 2-hop experiments to further enhance the fidelity of VLF prediction codes.
- Use results of ground-based SOH experiments to develop requirements for a space-based SOH demonstrator.
- Perform space-based SOH demonstration.

	FY 2005	FY 2006	FY 2007
Suborbital Space Launch Operations / Improving Suborbital Operations	4.800	5.600	0.000

(U) The Suborbital Space Launch Operations/Improving Suborbital Operations program will design and develop an unmanned, reusable suborbital launch vehicle whose near term goal is to perform short duration testing of space flight hardware and ultimately to provide a platform for tactical battlefield surveillance.

(U) Program Plans:
- Designed and tested a restartable propulsion system for ascent and descent.
- Developed payload concepts for battlefield surveillance and sensor insertion.
- Developed a preliminary system design for the launch vehicle.
- Conduct system requirements review and initiate detailed design.

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	FY 2005	FY 2006	FY 2007
Space Assembly and Manufacture	4.200	0.000	0.000

(U) The objective of the Space Assembly and Manufacture program was to examine and validate technical options for manufacturing and assembling large space structures outside the confines of the Earth's gravity. Manufacturing in the space environment would enable novel structures that otherwise would not survive the loads experienced during terrestrial launch as well as the production of extremely large structures that enable large optical systems providing resolution and accuracy that are not otherwise conceivable. The size of such structures is currently limited by volume constraints of launch vehicle fairings. Such structures are important to address both national security and energy issues.

(U) The Space Assembly and Manufacture program identified key technical challenges and development areas for conducting a demonstration mission. These included: resource utilization, robotic processing, enabling structures and materials, power management, and manufacturing processes that can take advantage of the space environment. The program examined the feasibility of a number of manufacturing processes, including vacuum deposition, extrusion, nanotube utilization, and surface finishing.

(U) Program Plans:
- Identified key technical challenges and defined a demonstration mission to resolve critical issues for space manufacture.
- Complete final report.

	FY 2005	FY 2006	FY 2007
Electro-Dynamic Tethers	2.800	0.000	0.000

(U) The Electro-Dynamic (ED) Tethers program explored novel military space applications of tether-like structures. These included high-voltage electro-static designs that rapidly remediate high energy radiation particles produced by a High Altitude Nuclear Detonation (HAND). ED tethers also had the potential to provide novel propulsion and power generation by alternating the direction of the electric current flow along its

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length in the presence of the magnetic field and plasmasphere. This feature might enable the creation of a transformational military space propulsion and energy source—without the use of consumables—when an ED tether is attached to a satellite.

(U) Program Plans:

- Completed analytical analysis for tether HAND remediation, propulsion and power generation performance expectation.
- Developed candidate ES tether system design.
- Ground tested key high-voltage electro-dynamic tether components.

	FY 2005	FY 2006	FY 2007
Micro Electric Space Propulsion	3.800	3.857	4.689

(U) The Micro Electric Space Propulsion program (MEP) will demonstrate flexible, light-weight, high-efficiency, scalable micro-propulsion systems to enable a new generation of fast, long-lived, highly flexible, and highly maneuverable 1-100 kg-class satellites/spacecraft. In particular, the goals of the program are to demonstrate a thruster system capable of: (1) varying its specific impulse in real time across a range from 500 seconds to 10,000 seconds utilizing a single propellant, (2) operating with electrical thrust efficiencies in excess of 90% over significant portions of this range, (3) demonstrating a thruster specific mass less than 0.3 g/watt, and (4) demonstrating a propulsion system capable of delivering total mission delta-Vs for a 100 kg satellite in excess of 10 km/s. The MEP technology is planned for transition to the Air Force at the conclusion of Phase I, which is anticipated to be completed in FY 2007.

(U) Program Plans:

- Demonstrate proof-of-principle 1 watt thruster system capable of operating 50% efficiency at 2500 seconds and 7000 seconds specific impulse.
- Design of 2-D thruster array.
- Develop and demonstrate required Microelectromechanical Systems (MEMS) fabrication process, including development of high-aspect ratio machining and conformal surface modification techniques.
- Develop robust system design capable of tolerating single emitter failure.

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– Initiate propellant selection and optimization.
– Demonstrate thruster / propellant material compatibility.
– Demonstrate thruster operation.

	FY 2005	FY 2006	FY 2007
RAD Hard by Design	10.250	10.000	6.000

(U) This program, formerly titled Radiation Resistant Mixed Signal Electronics, will develop, characterize, and demonstrate microelectronic design technologies to enable fabrication of radiation hardened electronic components using leading-edge, commercial fabrication facilities. The current mainstream approach for fabricating radiation-hardened electronics depends on specialized process technologies and dedicated foundries that serve this military market niche. While commercial semiconductor fabrication is not explicitly radiation hardened, recent trends in deeply scaled fabrication such as very thin oxides, trench isolation, and multiple levels of metal are resulting in semiconductor devices that are inherently more tolerant of radiation than older generations. This program will pursue development design-based technologies that couple into pure commercial fabrication technologies to attain radiation hardened electronics equivalent to those from the dedicated foundries. The design technology developed under the Radiation Hardening by Design Program is planned for transition to the Air Force and to the Defense Threat Reduction Agency (DTRA) at the end of Phase 2 which is anticipated to be completed by FY 2007. Specific design libraries for hardened circuits will transition through the defense electronics design industry, which are being supported largely by DTRA and the Air Force.

(U) Program Plans:
– Prove that a pure design-based approach will be capable of attaining radiation hardened electronic devices with less than one generation penalty in terms of device area, speed, and power.
– Create design libraries needed for implementing integrated circuits.
– Demonstrate the ability to design and fabricate a fully hardened complex circuit using developed design-based methodology.

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	FY 2005	FY 2006	FY 2007
Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP)	6.600	7.000	8.000

(U) The Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP) program will develop the advanced technologies, capabilities and space environment characterization required to demonstrate a suite of advanced lightweight microsatellite technologies integrated into high performance microsatellites across the continuum from low earth orbit (LEO) to deep space Super geo-synchronous orbit (GEO) environment. The program will integrate a variety of advanced technologies, which have not been previously flight-tested, and may include: lightweight optical space surveillance/situational awareness sensors, lightweight power, chemical and electric propulsion systems, advanced lightweight structures, advanced miniature RF technology including micro crosslink and use of Commercial Off the Shelf (COTS) approaches, active RF sensor technology, COTS processor and software environment, miniature navigation technologies, and autonomous operations. The developed capabilities may include high thrust, high efficiency solar thermal propulsion systems that can enable responsive orbit transfer as well as provide radiation resistant high density electrical power; ultra-stable payload isolation and pointing systems; and components to enable advanced miniature communication systems. The program will also consider affordable, responsive fabrication and integration approaches and the possibility of networking microsatellites/modules to create a flexible architecture of assets responsive to multiple missions and threats. If successful, MiDSTEP will demonstrate these technologies in space through Microsatellite Technology Experiments (MiTEx) and will support a variety of potential microsatellite projects.

(U) Program Plans:

- Conduct system design trades of appropriate technologies.
- Perform mission utility assessments and feasibility studies and develop concepts of operation.
- Design and develop microsatellite system concepts and integrate selected technologies.
- Perform component and subsystem ground tests, fabricate and flight test microsatellite system.

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	FY 2005	FY 2006	FY 2007
System F6	0.000	9.235	12.224

(U) The goal of System F6 program is to demonstrate a space system composed of a heterogeneous network of formation flying or loosely connected modules that will, working together, provide at least the same effective mission capability of a large monolithic satellite. Current large space systems used for national security purposes are constrained due to their monolithic architecture. They can be launched only on a small number of large launch vehicles, cannot readily be upgraded and/or reconfigured with new hardware on-orbit, and are risk-intensive, since the unforgiving launch and space environments can result in a total loss of investment with one mistake. Decomposition of a monolithic spacecraft into a fractionated space system offers the potential for reduced risk, greater flexibility (e.g. simplified on-orbit servicing, reconfigurability to meet changing mission needs), payload isolation, faster deployment of initial capability, and potential for improved survivability. This program will develop, design, and test new space system architectures and technologies required to successfully decompose a spacecraft into fundamental elements. Such architectures include, but are not limited to, ultra-secure intra-system wireless data communications, wireless power systems, electromagnetic formation flying systems, remote attitude determination systems, structure-less optical and RF arrays, and distributed spacecraft computing systems.

(U) Program Plans:

- Conduct system design trades of appropriate technologies and system architectures.
- Perform mission utility and econometric-based value assessments and feasibility studies and develop concepts of operations.
- Design and develop fractionated system concepts and integrate selected technologies.
- Perform component and subsystem ground tests.
- Fabricate and space test a microsatellite-scaled fractionated space system.

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	FY 2005	FY 2006	FY 2007
Front-end Robotics Enabling Near-term Demonstration (FREND)	0.000	9.100	13.445

(U) The goal of the Front-end Robotics Enabling Near-term Demonstration (FREND), formerly Spacecraft for the Universal Modification of Orbits (SUMO), program is to design, develop, demonstrate and fly technologies to increase survivability and operational effectiveness of commercial and military spacecraft. Currently, spacecraft parameters identify the state-of-health of vehicles leading to predetermined end-of-life criterion. FREND will enable continued safe operations and service life extension to these spacecraft. FREND combines detailed stereo photogrammetric imaging with robotic multi-degree-of-freedom manipulators to autonomously grapple space objects without custom interfaces. FREND offers the potential for spacecraft salvage, repair, rescue, reposition, and debris removal to extend service life or provide a safe and calculated de-orbit. Specific objectives of the FREND program include: development and demonstration of an autonomous rendezvous and grapple front end system; an effective, low total ownership cost design for the FREND system; and specific mission capabilities for geo-synchronous orbits (GEO). The anticipated transition partner is USAF Space Command.

(U) Program Plans:
- Design fabrication and ground testing of the sensing and robotic payload using flight hardware.
- Complete risk reduction lab test.
- Develop control algorithms for autonomous grapple and contingency operations.
- Procure and fabricate flight hardware for integration and testing.
- Conduct robotic payload ground test.
- Test control schemes in 1G environment.
- Conduct hardware-in-the loop testing in proximity operations test facility.
- Work with mission partner for full system integration and mission.

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	FY 2005	FY 2006	FY 2007
X-ray Navigation and Autonomous Position Verification (XNAV)	2.834	5.200	8.550

(U) The X-ray Navigation and Autonomous Position Verification (XNAV) program is expanding a technology thrust from the MiDSTEP program. It is an Advanced Technology Demonstration (ATD) involving the use of periodic x-ray celestial sources to determine the three-dimensional position, attitude and time of orbiting spacecraft. XNAV will develop, explore, and demonstrate the concept of operations (CONOPs) of a spacecraft equipped with an x-ray imager and photon counter to determine the feasibility and accuracy of x-ray pulsar sources for autonomous position, attitude and time determination in low earth orbit (LEO) for DoD navigation and communication satellites. The objective of the program is to develop a space qualified payload consisting of a gimbaled x-ray imager and photon counter that can be integrated and flown as an experiment aboard the International Space Station (ISS) Express Pallet, a NASA developed platform for space based experiments in support of DoD and NASA missions. The anticipated transition partner is USAF Space Command.

(U) Program Plans:
- Determine x-ray detector sensitivity, response time, signal-to-noise properties and timing electronics.
- Demonstrate expected navigation performance via detailed simulation.
- Successfully catalogue properties of rotation powered pulsar sources for navigation.
- Determine proper orientation of payload on ISS Express Pallet for optimum navigation performance.
- Develop preliminary x-ray detector system designs developed for the ISS Express Pallet.
- Select single x-ray detector design for development.
- Manufacture x-ray detector payload for ISS Express Pallet.
- Determine space qualifying payload.
- Conduct flight demonstration.
- Evaluate navigation performance.

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	FY 2005	FY 2006	FY 2007
Joint NASA/DoD Development	8.500	0.000	0.000

(U) The Joint NASA/DoD Development program coordinated related technology efforts between NASA and DARPA to ensure that both organizations derived the most benefit from each other's investments. NASA has initiated a program titled, Project Constellation, to fulfill the Vision for Space Exploration for missions to the lunar surface and beyond. This includes both robotic and crewed elements. NASA has identified the need for an in-space servicing to support this vision. The robotic autonomous proximity operations docking, fuel transfer, and in-space upgrade technologies under development in the Orbital Express (OE) program are directly applicable to the various aspects of Project Constellation. This program enabled DARPA and NASA to jointly investigate optimum operational concepts for mixed robotic and crewed operations.

(U) Program Plans:

- Designed fuel transfer system for bi-propellant cryogenic fuel transfer system.
- Developed CONOPS for manned- robotics collaboration in-space.
- Designed a robust proximity operations sensor suite based.

	FY 2005	FY 2006	FY 2007
Fast Access Spacecraft Testbed (FAST)	0.000	0.000	4.300

(U) The goal of the Fast Access Spacecraft Testbed (FAST) program is to demonstrate a suite of critical technologies required to perform rapid orbital repositioning in the geosynchronous belt. A high-efficiency, high-power (50-80 kW) fast-transfer roaming satellite would permit on-demand access to any point on the geosynchronous ring or within the high-altitude, supersynchronous "graveyard" (where derelict systems are regularly repositioned in order to free up orbital slots within the ring), greatly improving our space situational awareness capabilities. The FAST demonstrator satellite, while possessing high power, would be revolutionary in its small size. At just 500 kilograms, the FAST spacecraft would carry a novel solar power collection and distribution system, composed of large-aperture (5-10 m diameter) concentrating mirrors, high-efficiency

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solar photovoltaics, and ultralightweight, deployable radiators, achieving specific power (watts/kilogram) levels an order of magnitude better than today's state of the art.

(U) Program Plans:

- Conduct system design trades and investigate utility of applicable power and propulsion technologies.
- Perform preliminary design and technology selection.
- Perform detailed design and development of the FAST spacecraft, integrating selected technologies.
- Fabricate, qualify, and launch the FAST spacecraft to a low earth orbit to demonstrate proof-of-concept.

	FY 2005	FY 2006	FY 2007
Tiny, Independent, Coordinating Spacecraft (TICS)	0.000	0.000	4.800

(U) The Tiny, Independent, Coordinating Spacecraft (TICS) program is intended to leapfrog the microsatellite revolution, not simply through downsizing but through the addition of advanced robotics technologies to allow satellites to reconfigure on demand, many times over during the course of a mission. TICS will develop key technologies to permit the delivery of small, difficult-to-detect nanosatellites (1-10 kg) into any common operational orbit, from low earth orbit (LEO) to geosynchronous orbit (GEO), with little or no advance warning. TICS could be hosted aboard "mothership" platforms in LEO or GEO, or could be delivered directly via ultra-light launch platforms. Such systems could perform rapid-response reconnaissance on any spacecraft, with times to mission orbit measured in just hours. Such systems would be composed of modular, dockable subassemblies that could autonomously modify their morphologies to become apertures, free-flying formations, crawlers, or booms, as dictated by mission need. A TICS aggregate will be capable of assembling, disassembling, dispersing, and subsequently re-assembling, several times over. Enabling technologies include high-efficiency, miniaturized radar and active/passive optical sensors, multi-functional structures, software for advanced autonomous behavior (to include the ability to rendezvous, dock, undock, and formation-fly in multiple configurations), electric or chemical microthrusters, high energy density storage systems (including supercapacitors and advanced batteries), high efficiency energy conversion, and robust end effectors.

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(U) Program Plans:
- Conduct system design trades and provide "proof-of-concept" for a strawman TICS architecture.
- Conduct preliminary design, analysis, and key technology demonstrations.
- Perform detailed design and development of a TICS nanosatellite, integrating selected technologies and demonstrating aggregate behavior in a simulated space environment.
- Fabricate, qualify, and launch 5-10 TICS nanosatellites into low earth orbit, demonstrating multiple morphologies and missions.

(U) **Program Change Summary:** *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	222.880	223.811	264.291
Current Budget	217.004	216.357	254.913
Total Adjustments	-5.876	-7.454	-9.378
Congressional program reduction	-0.171	-13.054	
Congressional increases	0.000	5.600	
Reprogrammings	0.000		
SBIR/STTR transfer	-5.705		

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(U) Change Summary Explanation:

FY 2005	Decrease reflects DOE transfer as directed by P.L. 108-447 and the SBIR/STTR transfer.
FY 2006	The decrease reflects the $10M congressional cut to Space Assembly and Manufacture, undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission. These were offset by a congressional add to Improved Suborbital Operations.
FY 2007	Decrease reflects cancellation of the Space Assembly and Manufacture program and minor shifts in program pricing and phasing.

(U) Other Program Funding Summary Cost:

Orbital Express Space Operations Architecture	FY 2005	FY 2006	FY 2007
Joint NASA/DoD Development	4.000	0.000	0.000

Falcon	FY 2005	FY 2006	FY 2007
PE 0604855, Air Force SPC	30.362	23.354	16.000
PE 0604856, Air Force SPC	14.464	23.000	26.500
NASA	3.560	0.000	0.000

Deep View	FY 2005	FY 2006	FY 2007
PE 0305910F, Air Force SPC	13.960	8.840	8.720

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	216.824	220.877	248.627	236.675	225.765	207.051	195.351
Electronic Module Technology MT-04	13.357	0.000	0.000	0.000	0.000	0.000	0.000
Centers of Excellence MT-07	5.000	5.050	4.000	0.000	0.000	0.000	0.000
Advanced Lithography MT-10	25.094	0.000	0.000	0.000	0.000	0.000	0.000
MEMS and Integrated Micro-systems Technology MT-12	33.610	50.589	53.432	51.892	39.862	22.962	10.262
Mixed Technology Integration MT-15	139.763	165.238	191.195	184.783	185.903	184.089	185.089

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

(U) The Advanced Electronics Technology program element is budgeted in the Advanced Technology Development Budget Activity because it seeks to design and demonstrate state-of-the-art manufacturing and process technologies for the production of various electronics and microelectronic devices, sensor systems, actuators and gear drives that have military applications and potential commercial utility. Introduction of advanced product design capability and flexible, scalable manufacturing techniques will enable the commercial sector to rapidly and cost-effectively satisfy military requirements.

(U) The Electronic Module Technology project was a broad initiative to decrease the cost and increase the performance of weapon systems through the insertion of electronic modules. Electronic module technology addressed the design and fabrication of various types of digital, analog and mixed signal modules consisting of electronic, electro-optical and micro-mechanical components.

(U) Advanced Lithography technology enabled the dramatic growth of integrated circuit capability. Advances led to improvements in electronic and computing systems performance in terms of speed, power, weight and reliability. Further improvements require microcircuits with smaller features to meet the operational speed, power, weight and volume constraints.

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(U) The Microelectromechanical Systems (MEMS) and Integrated Microsystems Technology project is a broad and cross-disciplinary initiative that is developing an enabling technology that merges computation and power generation 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 and electro-chemical-mechanical 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.

(U) The Centers of Excellence project finances demonstration, training and deployment of advanced manufacturing technology at Marshall University.

(U) **Program Change Summary:** *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	222.777	214.378	239.813
Current Budget	216.824	220.877	248.627
Total Adjustments	-5.953	6.499	8.814

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Congressional program reductions	-0.174	-3.201
Congressional increases	0.000	9.700
Reprogrammings	0.000	
SBIR/STTR transfer	-5.779	

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

FY 2005	Decrease reflects the DOE transfer for P.L. 108-447 and the SBIR/STTR transfer.
FY 2006	Increase reflects four congressional adds to various advanced electronics offset by undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Increase reflects added funding for the Centers of Excellence in Project MT-07 and minor program repricing.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Centers of Excellence MT-07	5.000	5.050	4.000	0.000	0.000	0.000	0.000

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

(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 facility and initiatives to local area industries to utilize computer-integrated manufacturing technologies and managerial techniques to improve manufacturing productivity and competitiveness. Training emphasizes technologies to significantly reduce unit production and life cycle costs and to improve product quality.

(U) <u>Program Accomplishments/Planned Programs:</u>

	FY 2005	FY 2006	FY 2007
Advanced Flexible Manufacturing	4.000	4.000	4.000

(U) Program Plans:
- Continue the assessment of the Institute for Advanced Flexible Manufacturing's performance and transition from DoD to state/private support.

	FY 2005	FY 2006	FY 2007
Defense Techlink Rural Technology Transfer Project	1.000	1.050	0.000

(U) Program Plans:
- Provide funding for the Defense Techlink Rural Technology Transfer Project.

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

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY	R-1 ITEM NOMENCLATURE
RDT&E, Defense-wide BA3 Advanced Technology Development	Advanced Electronics Technology PE 0603739E, Project MT-12

COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
MEMS and Integrated Micro-systems Technology MT-12	33.610	50.589	53.432	51.892	39.862	22.962	10.262

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

(U) The Microelectromechanical Systems (MEMS) program is a broad, cross-disciplinary initiative to merge 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 applies 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.

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(U) <u>Program Accomplishments/Planned Programs:</u>

	FY 2005	FY 2006	FY 2007
Micro Power Generation	1.949	4.207	3.000

(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 will 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-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. The program will also explore innovative micro-scale, integratable power sources to provide high density energy sources. The Micro Power Generation program is anticipated to transition via industry to dismounted warrior and unattended ground sensor network programs under development by the Army.

(U) Program Plans:

– Demonstrated capabilities in fuel processing, energy conversion to electricity, and thermal and exhaust management.
– Demonstrated MEMS micro heat engines utilizing micropower sources.
– Demonstrate integration of various power-generation components with microsensors and microactuators.
– Demonstrate stand alone, remotely distributed microsensors and actuators with built-in power supply and wireless communication.
– Establish design paradigm-shifts that occur when implementing novel power sources at the micro-scale using MEMS technology.

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	FY 2005	FY 2006	FY 2007
Harsh Environment Robust Micromechanical Technology (HERMIT)	16.239	16.439	12.772

(U) The Harsh Environment Robust Micromechanical Technology (HERMIT) Program is developing micromechanical devices that can operate under harsh conditions-e.g., under large temperature excursions, large power throughputs, high g-forces, corrosive substances, etc.—while maintaining unprecedented performance, stability, and lifetime. Micromechanical RF switches are of particular interest, where sizable power throughputs and impacting operation constitute harsh operational environments. Other applications such as vibrating resonator reference tanks, gyroscopes, and accelerometers are also of interest. Among the HERMIT implementation approaches deemed likely to succeed are two of most interest: (1) wafer-level encapsulation or packaging strategies based on MEMS technology that isolate a micromechanical device from its surroundings while maintaining a desired environment via passive or active control; or (2) material and design engineering strategies that render a micromechanical device impervious to its environment, with or without a package (if possible). A key approach in this program that should allow orders of magnitude power savings is to selectively control only the needed micro-scale environment or volume via MEMS-enabled isolation technologies. The success of this program should enable a myriad of strategic capabilities, including lower cost, more complex phased array antennas for radar applications; tiny frequency references with long- and short-term stabilities that greatly extend the portability of ultra-secure communications; and micro-scale inertial measurement units with bias stabilities approaching navigation-grade. The HERMIT program is anticipated to transition via industry to phased array antenna, reconfigurable communication front-end, seeker, and steerable aperture programs being developed by the Army, Navy, and Air Force, as well as to inertial navigation systems and Joint Tactical Radio System (JTRS) communications needs by these Services.

(U) Program Plans:

– Establish the feasibility of encapsulating micromechanical devices under low-cost, wafer-level packages with minimal out-gassing or leaking and with minimal impact on device performance.
– Demonstrate engineered materials and/or surface treatments that render a micromechanical device impervious to its surroundings or operating environment.
– Demonstrate essential elements (e.g., thermistors, heaters, getters, etc.) needed for low power control of the operating environment surrounding a micromechanical device.

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– Demonstrate micromechanical devices (e.g., RF switches, vibrating resonators, etc.) fully integrated together with environment isolating measures (including circuits, if any) that maintain unprecedented performance, stability, and reliability, even under harsh environments.

	FY 2005	FY 2006	FY 2007
Chip-Scale Gas Analyzers	10.574	14.946	13.930

(U) The Chip-Scale Gas Analyzer Program will utilize the latest MEMS technologies to implement separation-based analyzers (e.g., gas chromatographs, mass spectrometers, poly-chromator-like devices) at the micro-scale to greatly enhance the selectivity of sensors to specific species, and thus, enable extremely reliable, remote detection of chemical/biological agents. The use of MEMS technology should also increase analysis speed and make possible the operation of such complex analyzer systems at extremely low power levels-perhaps low enough for operation as autonomous, wireless sensors. The many challenges in this program include the exploration and realization of micro-scale preconcentrator approaches, stacked gas columns, multiple sensor arrays, ionizers, vacuum pumps, and vacuum packaging. The success of this program will yield sensors substantially more selective than conventional sensors, again, making them particularly suitable for detection and identification of airborne toxins. The Chip-Scale Gas Analyzers program is anticipated to transition via industry to Chemical Warfare Agents (CWA) detector programs being developed by the Defense Threat Reduction Agency (DTRA) and the Army Soldier and Biological Chemical Command (SBCCOM).

(U) Program Plans:

– Establish design trade-offs in (column) length vs. species separation efficiency for micro-scale gas chromatographs, mass spectrometers, resonator-based separation mechanisms, etc.
– Demonstrate MEMS-enabled, micro-scale preconcentrators and explore the degree to which they enhance separation efficiency and species detectability.
– Demonstrate MEMS-enabled, micro-scale separation columns, ionizers, electromagnetic field generators, vacuum pumps, gas sensor arrays, calibration sources, all needed for separation-based analyzers.

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– Demonstrate advanced methods for making micromechanical sensor elements species sensitive (e.g., combinations of absorption spectroscopy and resonators coated with species-and-light sensitive films).
– Implement fully functional, MEMS-enabled gas separation analyzers with power consumptions small enough for autonomous, remote operation and with control electronics integrated directly.

	FY 2005	FY 2006	FY 2007
MEMS Exchange	4.368	3.067	3.000

(U) This program seeks to provide flexible access to complex Microelectromechanical Systems (MEMS) fabrication technology in a wide variety of materials and to a broad, multi-disciplinary user base via the MEMS Exchange service. A major goal of the effort is to ensure self-sustained operation of MEMS Exchange after the end of the program by adding several process modules to the existing repertoire and increasing the number of processes run per year so as to raise revenues to the point of self-sufficiency. Among the future payoffs of this program is the establishment of an accessible infrastructure for low or medium volume production of MEMS-enabled products for DoD applications. The MEMS Exchange program is anticipated to become self-sufficient within the next 5 years, at which point it will be able to provide MEMS fabrication services to all levels of industry and academia in support of Army, Navy, Air Force, and other DoD requirements without further DARPA sponsorship.

(U) Program Plans:
– Demonstrate online software capable of error checking and optimize process flow input by users so as to reduce the turn-around time per run and increase success rate.
– Insert a MEMS process module into the MEMS Exchange repertoire and make it available for use.
– Double the number of runs processed per year, to achieve a goal rate of 500 runs per year.
– Provide a modular merging process that combines modules together with transistor integrated circuits.
– Insert MEMS technology into three DoD applications using MEMS Exchange as the fabrication vehicle.

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	FY 2005	FY 2006	FY 2007
Low Power Micro Cryogenic Coolers	0.480	4.930	4.730

(U) The Low Power Micro Cryogenic Cooler program will attain superior performance in micro-scale devices (e.g. Low Noise Amplifier (LNA's) IR detectors, RF front-ends, superconducting circuits) by cooling selected portions to cryogenic temperatures. The key approach in this program that should allow orders of magnitude power savings is to selectively cool only the needed volume/device via MEMS-enabled isolation technologies. Such an approach will benefit a large number of applications where performance is determined predominately by only a few devices in a system, e.g., communications where the front-end filter and LNA often set the noise figure; and sensors, where the transducer and input transistor in the sense amplifier often set the resolution. MEMS technology will also be instrumental for achieving micro-scale mechanical pumps, valves, heat exchangers, and compressors, all needed to realize a complete cryogenic refrigeration system on a chip. Transition of this technology is anticipated through industry, who will incorporate elements of the technology in current and future weapon system designs.

(U) Program Plans:

- Obtain high thermal isolation using MEMS technology, despite high surface-to-volume ratios of micro-scale elements.
- Demonstrate micro-scale compressors with sufficient efficiency for low power operation.
- Demonstrate heat exchangers, Joule-Thompson plugs, valves, pumps, all needed for cryo-cooler implementation.
- Integrate micro cooler components together with sufficiently isolated devices to-be-cooled to yield a single chip system.

	FY 2005	FY 2006	FY 2007
Chip-Scale Atomic Sensors	0.000	7.000	9.000

(U) The Chip-Scale Atomic Sensors program will develop universally reconfigurable microsensors (e.g., for magnetic fields, temperature, pressure) with unmatched resolution and sensitivity. These devices will use the latest in MEMS and photonic technologies to harness perturbations in atomic transitions as the sensing and measuring mechanisms for various parameters. Currently, some of our best sensors achieve their performance via readout mechanisms based on the frequency of mechanical resonators, which can be determined with high resolution. Chip-

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scale atomic sensors would work on a similar principle, still using a time or frequency-based readout, but with substantially better resolution enabled by their much more stable atomic-clock-like readout. Furthermore, such sensors can be made reconfigurable by merely switching to atomic transitions that are strongly susceptible to certain stimuli, but insusceptible to others. If successful at achieving a universal sensor, the Chip-Scale Atomic Sensor program would not only provide sensors with unmatched performance, but would also be the key to lowering the cost of such sensors, since the production volumes for a universal sensor should be enormous.

(U) Program Plans:
- Develop a tunable microwave local oscillator to excite and select different hyperfine transitions.
- Integrate sensing transducers into atomic cells.
- Develop atomic cell wall coatings to mitigate the need for high cell pressure.

	FY 2005	FY 2006	FY 2007
Site-Specific Thermal Management (SSTM)	0.000	0.000	3.000

(U) The Site-Specific Thermal Management (SSTM) program will develop new approaches to removing local hot-spots that limit the performance of high-speed signal processing electronics, radar imaging systems, optoelectronic devices, and other systems characterized by above-ambient thermal issues. This program will provide a natural complement to the Low Power Micro Cryogenic Coolers program by addressing the performance-critical issue of excessive heat removal. The SSTM program will consider both monolithic and heterogeneous thermal management approaches based on variety of thermal materials and heat removal methods. Examples include: self-powered liquid spray cooling, integral copper heat pipes, microfluidic channels and diamond interposer layers.

(U) Program Plans:
- Identify and apply new integrated technologies for the thermal management of microsystems.
- Develop and integrate cooling approaches using new materials.

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	FY 2005	FY 2006	FY 2007
Micro-Beam Clocks	0.000	0.000	4.000

(U) The Chip Scale Atomic Clock (CSAC) program (budgeted in PE 0602716E, Project ELT-01) will demonstrate the potential of shrinking high precision time references by exploiting advances in micromachining, photonics, and electronics technology. The Micro-Beam Clock program will extend the accuracy of miniature clock by exploiting the precision of nuclear particle transport. The concept of beam clock has been known at least since the 1960's but has not been widely pursued due to the difficulty in containing a large volume of xenon gas. This problem will be addressed by going to the micro-scale. Miniaturization of the conventional beam clocks with major innovations are possible due to microscale implementation – microscale xenon atom source, micromachined permanent magnets, and micromechanical atom flux detectors. This approach will not only improve the stability over existing CSAC but will further reduce the required power.

(U) Program Plans:
- Generate sufficient atom flux using adsorption-desorption control at microscale.
- Detect atoms in flight using micro-cantilever array – Brownian noise limited.
- Determine permanent magnet laser cutting at microscale.
- Determine High B-field gradients at microscale.
- Determine pressure measurement in presence of high magnetic field with MEMS pressure sensors.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Mixed Technology Integration MT-15	139.763	165.238	191.195	184.783	185.903	184.089	185.089

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

(U) The goal of the Mixed-Technology Integration project is to leverage advanced microelectronics manufacturing infrastructure and DARPA component technologies developed in other projects to produce mixed-technology microsystems. These 'wristwatch size', low-cost, lightweight and low power microsystems will improve the battlefield awareness and security of the warfighter and the operational performance of military platforms. At the present time, systems are fabricated by assembling a number of mixed-technology components: Microelectromechanical Systems (MEMS), microphotonics, microfluidics and millimeterwave/microwave. Each technology usually requires a different level of integration, occupies a separate silicon chip and requires off-chip wiring, fastening and packaging to form a module. The chip assembly and packaging processes produce a high cost, high power, large volume and lower performance system. This program is focused on the monolithic integration of mixed technologies to form batch-fabricated, mixed technology microsystems 'on-a-single-chip' or an integrated and interconnected 'stack-of-chips'.

(U) The field of microelectronics incorporates micrometer/nanometer scale integration and is the most highly integrated, low-cost and high-impact technology to date. Microelectronics technology has produced the microcomputer-chip that enabled or supported the revolutions in computers, networking and communication. This program extends the microelectronics paradigm to include the integration of heterogeneous or mixed technologies. This new paradigm will create a new class of 'matchbook-size', highly integrated device and microsystem architectures. Examples of component-microsystems include low-power, small-volume, lightweight, microsensors, microrobots and microcommunication systems that will improve and expand the performance of the warfighter, military platforms, munitions and UAVs.

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(U) The program includes the integration of mixed materials on generic substrates including glass, polymers and silicon. The program is design and process intensive, using 'standard' processes and developing new semiconductor-like processes and technologies that support the integration of mixed-technologies at the micrometer/nanometer scale. The program includes the development of micrometer/nanometer scale isolation, contacts, interconnects and 'multiple-chip-scale' packaging for electronic, mechanical, fluidic, photonic and rf/mmwave/microwave technologies. For example, a mixed-technology microsystem using integrated microfluidics, MEMS, microphotonics, microelectronics and microwave components could provide a highly integrated, portable analytical instrument to monitor the battlefield environment, the physical 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) <u>Program Accomplishments/Planned Programs:</u>

	FY 2005	FY 2006	FY 2007
Digital Control of Analog Circuits RF Front Ends	12.102	13.742	5.000

(U) Digital Control of Analog Circuits will demonstrate analog/radio frequency (RF) electronic components that have the ability to self-assess and adapt in real time (sub microseconds), by self-tuning their impedance-matched networks and thereby extending the operational performance of analog components to the intrinsic semiconductor device limits. This technology will result in a new generation of analog, microwave and millimeter wave components with >150X improvements in power-bandwidth, linearity-efficiency products. This program will transition via industry in the form of integrated adaptive RF front-end components for a wide variety of applications used by the Services and intelligence agencies, particularly radar, space based communication, smart weapons, and electronic warfare systems.

(U) Program Plans:

- Demonstrate real-time active self-assessment and monitoring of RF/analog functions using nano-Complimentary Metal Oxide Silicon (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.

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- Develop techniques and algorithms to monitor active device status.
- Demonstrate MEMs tunable device optimization (<1 microsecond, 10:1 tuning ratio).
- Fabricate tunable MEMs control integrated circuits.
- Fabricate self-assessment control integrated circuits.
- Demonstrate device and algorithm concepts for intelligent self-assessment of analog functions.
- Demonstrate device concepts for 10^5 microsecond actuation time of impedance matched networks.
- Complete design concept for adaptable RF components.
- Demonstrate concept of digital assessment of analog device.
- Demonstrate reconfigurable network concept for 10^5 microsecond actuation time of impedance matched networks.
- Validate concept of adaptable RF components by demonstrate digital control of analog circuits.
- Identify component requirements and conduct component demonstrations.

	FY 2005	FY 2006	FY 2007
Chip Scale Wavelength Division Multiplexing (CS-WDM)	11.991	5.327	0.000

(U) The goal of the CS-WDM (Chip Scale Wavelength Division Multiplexing) program is to develop WDM photonic chips with multiple functionalities and dynamic reconfigurability. Such integration will result in considerable reduction in the size of the optoelectronic components needed for fiber optic networks. DARPA has a MOA with Navy for coordinated development of Highly Integrated Photonics (HIP) technology for demonstration, test and transition on the EA-6B Prowler and EA-18G airborne electronic attack (AEA) aircraft. The goal is to develop a common optical backplane on the aircraft in place of many point-to-point links. The restricted space available for fiber optic network puts a premium on reducing fiber optic device size. The CS-WDM program has thus laid the foundation for this transition opportunity with Navy.

(U) Program Plans:

- 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.

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- Plan construction of WDM components.
- Design, fabricate and test novel WDM components using the new materials and processing technology.
- Determine fiber optic and planar waveguide interconnection requirements.
- Evaluate the suitability of the new components for use in prototype modules.
- Down-select to the most promising approaches and begin prototype module assembly.
- Construct testbeds capable of fully measuring and characterizing the new technologies implemented in the chip-scale WDM components.
- Evaluate the performance characteristics of the prototype modules and determine the highest payoff dual use development paths.
- Evaluate and demonstrate network with device testing.
- Demonstrate network with completed modules.

	FY 2005	FY 2006	FY 2007
Optical Code Division Multiple Access (OCDMA)	16.653	6.380	0.000

(U) Optical CDMA represents a paradigm shift from the current Wavelength Division Multiplexing/Time Division Multiplexing (WDM/TDM) optical networks. Instead of assigning a wavelength and a time slot to a user, O-CDMA assigns a code to a user. The goal of this program is to demonstrate technology for an advanced O-CDMA communications system. Such a system potentially offers the benefit of multi-level security, low probability of interception, detection and jamming, decentralized network, and higher spectral efficiency. The O-CDMA program is anticipated to transition via industry to optical networking programs of interest to all Services.

(U) Program Plans:

- Demonstrate data transmission between 10 simultaneous users at 10 Gigabit/second per user with a low bit error rate.
- Demonstrate scalability to 100 simultaneous users and cardinality of 1000.
- Demonstrate spectral efficiency scalable to 1 bit/s-Hz.

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	FY 2005	FY 2006	FY 2007
Large Area Distributed Macroelectronics	7.400	6.100	0.000

(U) The Large Area Distributed Macroelectronics program will develop large area multifunctional actuation and sensing systems using novel combinations of active and passive electronics and flexible, conformable, non-traditional materials and techniques. It will develop basic technologies and techniques for component attachment, electrical interconnections, and multilayer routing and will utilize existing novel materials and designs for actuation and sensing such as electroactive polymers to achieve active porosity and fibers for acoustic response. This program will demonstrate prototype systems that achieve orders of magnitude improvements in performance and/or cost. Examples of applications include: control surfaces for an autonomous precision guided parafoil and controlled air boundary layers for reduction in drag for underwater vehicles; beam steered acoustic arrays with large apertures to achieve order of magnitude improvements in angle of coverage and signal to noise ratios; early warning threat detection and localization using a large area inflatable structure with woven antennas and electronics for high bandwidth communications; and aircraft or UAV wing skins for chem/bio monitoring.

(U) Program Plans:
- Develop enhanced transistors compatible with low cost, large area fabrication.
- Develop methods to print active circuits on large area and flexible circuits.
- Develop techniques to wirelessly communicate between circuit blocks over a distributed electronics surface.
- Develop novel circuit/microarchitectures to enhance system performance for demanding electronic applications.
- Demonstrate examples of large area and/or flexible substrate distributed electronics to address difficult problems in sensor networks, physical security systems, or radar beam forming/steering.

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	FY 2005	FY 2006	FY 2007
Adaptive Photonic Phased Locked Elements (APPLE)	5.991	6.546	10.000

(U) The goal of this program is to demonstrate a fully scalable and modular architecture of phased sub-apertures capable of producing an arbitrarily large optical aperture that can be rapidly and non-mechanically steered over a wide field of regard with high precision. This effort is anticipated to transition via industry.

(U) Program Plans:

- Develop sub-apertures to operate at wavelengths of 1.06 um, 1.55 um, 3-5 um, and 8-12 um.
- Demonstrate steering over a full 90 degree cone.
- Reduce parts counts, which will make certain laser systems affordable.
- Reduce weight, a particularly important goal for space-based applications.
- Develop and test a single APPLE aperture at the 50 watt optical power level.
- Introduce and verify a new material system for optical phased arrays and adaptive optical actuators to support the development path to higher power handling capability.
- Demonstrate by analysis the path to much lower loss electronic beam steering.
- Demonstrate by a combination of direct component measurements and advanced system modeling that an electronic beam control system, with optical loss of less than 2 dB, is feasible and supported by the development path.

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	FY 2005	FY 2006	FY 2007
Data in Optical Domain Network (DoD-Network)	9.498	10.400	11.372

(U) Currently optical networks use photonics to transport data and electronics to process data. However, as the underlying bit rates of the optical networks are pushed beyond 40 giga-bits per second, there will be significant processing bottlenecks in these networks and these bottlenecks will severely limit the military's ability to rapidly transport time critical information. A potential solution to this problem is to develop photonic technology so optics can take over higher order network processing functions. The DoD-Network program will develop and demonstrate four key photonic technologies to meet these challenges: all-optical routing, all-optical data buffering (controllable and eventually random access,), optical logic and circuits, and all-optical (multi-wavelength) regenerators. These photonic technologies will lead to intelligent all-optical networks. The program will have two major areas of interest: The first will focus on developing new photonic technology that is essential if photonics is to play a significant role in higher order processing in optical networks. The second area will focus on developing novel architectures that will fully exploit the new photonic technology to bring new and increased functionalities to the optical networks. The DoD-Network program is anticipated to transition via industry to high speed, high capacity optical networking programs of interest to the Air Force.

(U) Program Plans:

- Develop a limited (4x4 or 8x8) optical packet switch.
- Develop means for address processing.
- Develop multi-wavelength optical regenerators.
- Develop flexible, room temperature optical buffers.
- Develop synchronization techniques for short pulses.
- Develop controllable picosecond optical time delays.

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	FY 2005	FY 2006	FY 2007
Microantenna Array Technology & Applications (MIATA)	9.113	8.064	4.494

(U) The goal of the MIATA program is to develop low-cost arrays that can sense both Millimeter Wave (MMW) and IR scenes along with compact MMW designator sources for passive and active imaging applications in the spectral region from W-band (94 GHz) to the long wave infrared optical region. New micro- and nano-fabrication techniques of low cost antenna arrays provide a basis for revolutionary tactical military applications in the unexploited submillimeter to long wave optical spectral region. The military utility of this technology includes conventional passive imaging with compact devices at elevated temperatures, passive or active ballistic imaging through extreme weather and obscurants, polarization discrimination of manmade objects, rapid electronic spectral tuning for clutter discrimination, ultrawideband response (achieved using metal-insulator-metal tunneling structures for sensing/rectifying the antenna current), and may also include synthetic apertures, phased arrays, true time, and steered receiver beams. The MIATA program is planned for transition to the Army Research Laboratory at the conclusion of Phase 2, which is anticipated to be completed in FY 2007.

(U) Program Plans:

- Achieve 95 GHZ: Noise Equivalent Temperature Detection (NETD) $\leq$ 20 Kelvin (K) in a 2x2 array.
- Achieve 8-12 um: NETD $\leq$ 0.1 K in an 8x8 array.
- Achieve 95 GHZ: NETD $\leq$ 2 K in an 8x8 array.
- Achieve 8-12 um: NETD $\leq$ 0.02 K in a 64x64 array.

	FY 2005	FY 2006	FY 2007
Ultra Wide Band Technology	17.660	17.239	15.516

(U) Radar array antennas that use the Ultra Wide Band hold the promise of a new class of high coverage/high sensitivity systems. DARPA is tackling the issue through two programs: Ultra Wide Band Array Antenna, and Ultra Wide Band Multi-Function Photonic Transmit and Receive (ULTRA T/R) Modules.

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(U) The Ultra Wide Band Array Antenna program explored novel electronic array antenna and beamforming technology. The program goal was to support simultaneous electronic steering of more than 50 beams of arbitrary polarization, each with radio frequency range of 200 MHz to 20 GHz. The critical components to enable this include; fragmented antenna elements, free space optical time delays, a novel matrix beam former, and high-density electronics. The UWBAA program completed initial design studies and component demonstrations validating the ability to support instantaneous bandwidths. The program ended after the initial design phase.

(U) The objective of the ULTRA T/R program is to develop a wideband microwave antenna interface and corresponding antenna elements that would replace the conventional electronic T/R module-antenna combination and offer multiple modes of operation (e.g. simultaneous transmit and receive or switched mode), fiber interface to/from either digital or analog beamformer at significantly reduced size, weight, and power. The ULTRA T/R program is planned for transition to Navy and Air Force airborne C4ISR platforms and wideband phased-array antenna systems at the conclusion of Phase III, which is anticipated to be completed by FY 2007.

(U) Program Plans:

- Ultra Wide Band Array Antenna
  - Completed critical component feasibility demonstration – radiating element, optical beamformer.
  - Completed designs to support 100:1 instantaneous bandwidth.

- Ultra Wide Band Multi-Function Photonic T/R Module
  - Develop and demonstrate optical modulators, which exhibit low switching voltages and incorporate a long effective electrode length.
  - Fabricate and demonstrate high power photodiodes and photodiode arrays for T/R modules.
  - Develop a high-efficiency, high-power, low Relative Intensity Noise (RIN) laser operating at 1550 nm.
  - Develop high antenna T/R isolation through a) low return loss at the modulator/antenna interface; and b) low mutual coupling between antenna elements.

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	FY 2005	FY 2006	FY 2007
Flexible Nanocomposite Organic Photovoltaic Cells	6.750	4.700	0.000

(U) The goal of the Flexible Nanocomposite Organic Photovoltaic (PV) Cells has been to efficiently convert solar energy to electricity utilizing nanocomposite materials on flexible, lightweight substrates. Operational impact would be 200x increase in power/weight, longer operating time before resupply, increased sustainability, and greater mobility. The Flexible Nanocomposite Organic Photovoltaic technology is transitioning to the United States Special Operations Command, Directorate of Advanced Technology (SOAL-T). Commercial manufacturing is also anticipated which will improve the cost and availability of this technology for Service users.

(U) Program Plans:

- Delivered 2 cm^2 PV cell with increased efficiency from < 3% to 20%.
- Used plastic or fabric substrates in transparent electrode and heterojunction stability.

	FY 2005	FY 2006	FY 2007
Laser-Photoacoustic Spectroscopy (L-PAS)	10.992	8.747	8.190

(U) The goal of this program is to develop and demonstrate highly sensitive, compact, rapid, reliable, inexpensive, and low power consuming chemical agent sensors based on the principle of laser photoacoustic spectroscopy. The sensor will be capable of functioning to this level of performance for a wide variety of possible chemical agents, explosives, and narcotics in the presence of diverse background environments. LPAS will transition prototype chemical agent sensors to the Joint Science and Technology Office (JSTO), Defense Threat Reduction Agency, for evaluation. To that end, JSTO and DARPA are working closely to ensure that the final program metrics are properly aligned with the joint C/B community needs.

(U) Program Plans:

- Demonstrate working prototypes that have a sensitivity to <1ppb at a false alarm rate of better than 10^{-6}.

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– Demonstrate a major improvement in performance (measured in terms of sensitivity) over the Joint Chemical Agent Detector (JCAD) system, which is the next generation chemical sensor currently under development.

	FY 2005	FY 2006	FY 2007
High Operating Temperature - Mid-Wave Infrared (HOT MWIR)	0.000	11.675	16.811

(U) The objective of this program (formerly known as Room Temperature – Mid-Wave Infrared with Integral Signal Processing) is to establish technology for high-speed sampling and high spatial resolution infrared focal plane arrays that operate in the mid wave infrared without cryogenic cooling. The high sampling speed is required for both threat detection and for imaging from fast moving platforms. Technology goals are to achieve greater than an order of magnitude reduction in currents contributing to detector noise demonstrated with a high density, large area detector array format of up to 1280 x 720 elements. For imaging, the sensor will respond in a broad spectral band, including the mid and long wave infrared, and optimized for imaging at high frame rates with large field of view.

(U) Program Plans:
– Design new approaches necessary to reduce detector dark current and noise.
– Amplify the low level signal in multi-band mid-wave detectors.
– Develop micro-detectors, which collect signals from a large area while reducing the volume available for detector noise current generation.
– Demonstrate carrier extraction techniques in the laboratory to show potential excess current, while maintaining high signal levels.
– Develop noise suppression techniques to solid state cooler design to reduce operating temperature, without increasing power to the cooler.

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	FY 2005	FY 2006	FY 2007
Liquid Electronics Advanced Power Source (LEAPS)	3.800	11.000	10.575

(U) This program will develop technology to support direct nuclear-to-electrical conversion, in which a liquid semiconductor (LSMC) is used as a self-healing medium for capturing the energy of fission fragments in the form of electron-hole (e-h) pairs, and a collector of the e-h pairs. The liquid semiconductor will also serve as a medium in which to contain and disperse the nuclear fuel energy conversion. A general study of electronics based on liquid semiconductors will be included in this program. This program is anticipated to transition via industry.

(U) Program Plans:

- Develop the liquid semiconductor-based nuclear source and reactor.
- Implement a direct conversion cell using liquid semiconductor materials.
- Develop liquid semiconductors as self-healing materials for high stress environments.

	FY 2005	FY 2006	FY 2007
Visable/Short Wave IR - Photon Counting	0.000	7.322	6.027

(U) This program will develop imaging over a broad spectral band at extremely low levels of ambient illumination to provide a unique capability for remote sensing, unattended sensors, and pay-loads for autonomous ground and air platforms. Recent innovations in solid state imaging devices, including parallel processing at the pixel level and novel read read-out technology, can contribute to development of a new class of sensors, which can create an image with only a few photons per pixel, exceeding performance of current low light level imagers. The direct conversion of low light level information into an electronic format provides access to a suite of signal processing, image enhancement and communications techniques not available with current low light level imaging devices.

(U) Program Plans:

- Develop unique electronic read-outs with internal gain that boost low level signals above output amplifier noise.

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– Develop potential approaches to include distributed amplification in the read-out signal chain, avalanche multiplier gain internal to the pixel, and semiconductor optical amplification integrated with the detector.
– Extend silicon detector response into the near infrared by doping with narrow band gap materials to achieve a single imaging chip with response from the ultraviolet to near-infrared.
– Integrate with uncooled long wavelength infrared imagers through development of technology to transfer the thin film silicon onto the infrared imager, achieving an imaging chip with broad band response and photon counting sensitivity from ultra-violet to the infrared.

	FY 2005	FY 2006	FY 2007
Electronic & Photonic Integrated Circuits on Silicon (EPIC)	12.777	14.836	12.970

(U) This program will develop two critical alternative photonic technologies based on silicon substrates. The first thrust addresses active photonic components based on silicon, which do not rely on generating light within the material. While passive photonic components, such as waveguides, can be fabricated from silicon, silicon's indirect bandgap does not lend itself to fabricating active photonic components based on the generation of photons (lasers, amplifiers etc.). The first alternative technology development will be optical amplifiers using Raman gain. Fiber amplifiers based on Raman gain currently play a major role in optical networks, and demonstrating this optical amplification in silicon will be a major step toward overcoming on chip losses in complex chip-scale optical components. The second alternative technology development will address optical transistor action, or switching, in silicon, (i.e., a three-terminal optical device, in which control photons at one terminal will make a large change in the photons transmitted between the other two terminals). Taken together, these two capabilities will create a new paradigm, in which silicon will provide a platform for monolithic integration of photonic and electronic functions. The EPIC program is anticipated to transition via industry to optical communication and electronic warfare programs of interest to all Services.

(U) Program Plans:
– Demonstrate low-loss waveguides connecting optical gates and increased dynamic range for the logic gates.
– Demonstrate integrated processing functions such as adders and shift registers, requiring integration of 3-10 logic gates.

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	FY 2005	FY 2006	FY 2007
Space, Time Adaptive Processing (STAP) BOY	5.100	6.240	6.240

(U) This program will research, develop, and demonstrate miniature, low-power, low-cost, teraflop-level signal processing solutions derived from commercial Graphics Processor Unit (GPU) hardware and software of the type currently used for fast geometry computations in hand-held electronic games like Nintendo's GAME BOY®. Success in this program will allow the DoD to exploit the continuing phenomenal growth in both performance and programmability of GPU's resulting from competition in the multi-billion dollar international electronic entertainment industry. Particularly relevant advantages of recent GPU's over more traditional embedded processors include enhanced memory access bandwidth, hardware-accelerated floating-point vector geometry functions, low power consumption, and open source programming language support. The STAP BOY technology is planned for transition to the Army at the conclusion of Phase III, which is anticipated to be completed by FY 2008.

(U) Program Plans:

- Develop and characterize a prototype architecture using a single GPU and a Field Programmable Gate Array (FPGA) input-output structure.
- Demonstrate that the prototype system is capable of sustaining 100 Gflops potentially scalable to a multi-GPU pipeline mesh teraflop computing architecture, and is easily programmable to provide extremely high performance in diverse challenge problems.
- Demonstrate the single GPU prototype consisting of 1) adaptive algorithm for data structure simplification, suitable for adaptive weight computations in STAP and 2) 3-D tomographic reconstruction processing for aperture synthesis.

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	FY 2005	FY 2006	FY 2007
Vertically Integrated Sensor Arrays (VISA)	0.000	8.270	11.000

(U) Prior year funding for the VISA program was budgeted in PE0602716E; Project ELT-01 and has been combined with Resonant Nanosensors to address new architectures for three-dimensional focal plane arrays, where multiple levels of signal processing are integrated into each pixel in the array. This novel infrared focal plane architecture will be expanded to include multiple processing layers, higher density vias at the pixel, and coverage of a broad spectral band from the visible to the infrared. This increased on-chip processing power will enable new capability for smart sensors, such as high speed imaging, on-chip threat discrimination and anti-jamming. The VISA technology establishes a dramatically new approach to read-out electronics for imaging sensors, impacting multiple areas essential to Defense systems. The three-dimensional read-out architecture allows increased on-chip charge integration, dynamic range of eighteen to twenty bits, simultaneous registration of multiple wavelength bands, and high speed laser imaging. Specific system impacts include Mid / Long-wavelength target acquisition systems for air and ground; smart missile seekers, and anti-jamming, and imaging through high intensity sources.

(U) Program Plans:

- Demonstrate high dynamic range imaging sensors with an analog to digital converter at each pixel in the array.
- Design and develop three-dimensional focal plane architecture with multiple levels of signal processing at each detector in the array.
- Develop thru-via and interconnection technology with greater than 99% operability on 256x256 arrays.
- Demonstrate increased sensitivity realized by the large charge storage capacity of the three-dimensional focal plane circuit architecture.
- Develop low mass structures and high-Q resonators.
- Develop nanoparticle mass-load tags for enhanced sensitivity.

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	FY 2005	FY 2006	FY 2007
Analog Spectral Processors	0.000	0.000	5.500

(U) The Analog Spectral Processors (ASP) program will leverage existing MEMS capabilities to make precision RF components, and perform low-insertion-loss/heterogeneous components integration to demonstrate integrated Analog Spectral Processors that greatly reduce dynamic range and bandwidth requirement on A/D converters and other front-end components. This will enable proliferation of advanced RF capabilities to the individual war fighter by dramatic size, weight, and power of RF systems.

(U) Program Plans:
- Demonstrate large scale heterogeneous integration of MEMS resonators, MEMS switches, and RF active components to enable Analog Spectral Processor Front-Ends capable of arbitrarily sampling across at least three decades of bandwidth and dynamically compressing spectrum in terms of bandwidth and dynamic range so as to present only signals to the Analog Digital Converter.
- Demonstrate filter arrays.
- Demonstrate ASP.

	FY 2005	FY 2006	FY 2007
All-Dielectric Non Electronic RF Front-End (ADNERF)	0.000	0.000	4.500

(U) The All-Dielectric Non Electronic RF Front-End (ADNERF) program will create a wide bandwidth, tunable RF front end technology that is immune to electromagnetic pulse attack. This program will seek an entirely new approach to RF front-end technology where all metal and front-end electronic circuitry are eliminated. Of particular interest will be an all-dielectric, electronics-free RF front end with sensitivity and dynamic range consistent with today’s wireless communication and radar systems. By eliminating the metallic antenna, a secondary goal is to effect a significant reduction in detectable radar cross section.

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(U) All-Dielectric, Non-Electronic RF Front Ends (ADNERF) represent the ultimate solution for protecting wireless communication and radar systems. ADNERF can find immediate application protecting tactical communication and radar systems, which are highly vulnerable to electromagnetic pulse (EMP) attack due to their close proximity to enemy assets. As the efficiency and tunability of the all-dielectric non-electronics front-ends improve, the technology can become an ubiquitous RF front end for all military as well as commercial wireless devices, providing the communications infrastructure immunity against EMP attacks.

(U) Program Plans:
- Achieve high RF sensitivity.
- Develop innovative dielectric materials with high dielectric constant and low loss for efficient dielectric antennas.
- Determine if non-electronic signal transduction will be necessary.
- Develop material engineering approaches utilizing novel ferroelectrics and develop structural engineering techniques using photonic bandstructures approaches.
- Design resonant (RF and optical) structures in the appropriate materials.
- Achieve RF tunability for maximum utility.
- Achieve low power operation and small-form factor packaging of the ADNERF components for battery-operated mobile devices.

	FY 2005	FY 2006	FY 2007
Electronic Eye	0.000	0.000	5.000

(U) The objective of the Electronic Eye program is to demonstrate an artificial electronic eye that will eventually have many of the capabilities of the human eye. The basic idea behind this program is that organic materials can be fabricated on a flexible spherical substrate to produce an artificial eye. Organic materials have shown to have good electronic and optoelectronic properties including light emission and detection. A single lightweight, distortable, small f-number polymer convex lens with electrostatically-actuated artificial muscle will achieve distortion-free large field of view, high resolution and small f-number.

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(U) Program Plans:

- Demonstrate high quality organic devices for integration of different classes of devices (e.g. LED and transistor).
- Fabricate a large number of devices on a single substrate.
- Research and develop materials and devices, fabrication technology, and imaging systems architecture and engineering.
- Develop low cost, very high resolution and light weight imaging devices for a wide range of DoD applications.

	FY 2005	FY 2006	FY 2007
High Gain Optical Transceiver on a Chip	0.000	0.000	5.000

(U) The High Gain Optical Transceiver on a Chip program will address development of an ultra-compact, low power, solid state laser transceiver-on-a-chip (source and receiver), achieving with integrated circuit technology, the peak energy and narrow pulse width required for high resolution imaging. Two technical innovations will contribute to this new capability, large arrays of vertical cavity surface emitting lasers (VCSEL) integrated into a micro-chip; and the incorporation of high gain at receiver, specifically semiconductor optical amplifiers integrated with the detector to boost the laser signal return above receiver noise. The high optical gain at the receiver will add flexibility to trade-off laser power for solid state optical gain, and the capability to illuminate targets with extremely low optical power, providing a nearly-covert optical signal. Wavelength diversity augments the capability to illuminate difficult to detect optical signals.

(U) Currently, diode pumped lasers will require high peak energy to achieve 20 to 100 mj with the narrow pulse width (1 – 10 nsec) needed for imaging and targeting applications. These laser systems will be dramatically simplified with solid state arrays and have the potential to reduce size of these lasers from several pounds to a few ounces; while at the same time significantly increasing overall efficiency to as high as 80%. The solid state arrays avoid the efficiency loss in coupling optical energy into the gain medium, and eliminate conversion loss in the gain medium.

(U) Program Plans:

- Achieve the extremely high peak power required for imaging and targeting applications via design, integration, and packaging.
- Re-design VCSEL arrays to achieve the closed packaged density consistent with compound semiconductor manufacturing.

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- Demonstrate high peak energy per pulse at narrow pulse width, which requires both design and processing innovations to realize the interconnection of thousands of individual elements, while achieving the rapid response necessary for narrow pulses.
- Demonstrate improvements in individual device design specifically tailored for pulse mode operation that are necessary to achieve the high peak power required for imaging and ranging applications, which include novel cavity materials, reflective layers, spacing.
- Achieve thermal stability via device mounting and heating sinking.
- Develop complementary process for the semiconductor optical amplifier.
- Develop array compatible semiconductor optical amplification technology to achieve gain at the detector with the resolution required for imaging.
- Amplify low level optical returns with minimum excess noise while maintaining uniformity across the array.

	FY 2005	FY 2006	FY 2007
Nano Enabled Instruments	0.000	0.000	5.000

(U) The Nano Enabled Instruments program will apply key nanotechnologies such as materials functionalization, multi-domain scaling, and heterogeneous integration to realize new analytical instruments specifically designed to detect and quantify physical, chemical, and biological signatures. Technical approaches include scaling in the electrical, mechanical, optical, chemical, and biological domains; systems integration of new materials; application of nanofabrication methods and their resulting nanostructures; and, heterogeneous integration of micro- and nano-components.

(U) The overall goal is to realize new analytical instruments for superior performance and simultaneous reduction in size for a variety of defense applications. Examples of nanoinstruments of interest include ultra-small Raman spectrometers-on-a chip, IR microspectrometers, nanopolychromators, programmable spectral filters, intelligent nanoparticle systems, and label-free biological analyzers. The nanoinstruments to be realized will be generally applicable to expanding military needs for portable, handheld, and standoff detection and analysis capabilities.

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(U) Program Plans:

- Exploit physical scaling laws and various trade-off issues – for instance, mass scaling of inertial cantilever sensors leads to improvement in signal-to-noise (~$m^{-1/2}$).
- Demonstrate heterogeneous integration – lithographic registration of photon source, microoptics, and detector on a single chip.
- Demonstrate a potential lead to a rugged, miniature, and deployable (IR or Raman) microspectrometer.

	FY 2005	FY 2006	FY 2007
Nanophotonics for Ultradense On-Chip Communications	0.000	0.000	5.000

(U) The Nanophotonics for Ultradense On-Chip Communications program will make it possible to fabricate molecular systems (e.g. memories) with volume densities exceeding 1 trillion per cm^3 and transistors with areal densities exceeding 100 million per cm^2 and exceeding several billion per cm^2 in 10 years. These ultradense systems will be extremely powerful; however, the full potential of such systems will require communication to each nano-unit with appropriately high bandwidth, and provide high capacity/bandwidth input/output (I/O) to/from the chip containing such ultradense systems. The proposed program will demonstrate photonic technology to provide a solution for both.

(U) Nanophotonics will offer a potential solution to this enormous problem because of two very fundamental reasons: (1) the speed of light is at least 12 times larger than the speed of electrons, and (2) multiple wavelengths can be carried in the same waveguide without interacting with each other. These two fundamental benefits would enable high capacity/bandwidth access to ultradense systems on the chip as well as enable high capacity/bandwidth I/O to/from the chip. This program will transition via industry.

(U) Program Plans:

- Demonstrate nanophotonic technology for (1) access to on-chip ultradense systems and (2) for input/output to/from a chip containing such ultradense systems.
- Implement technical challenges that will be met to include: high precision, low loss nanophotonic circuit fabrication, low cost fabrication methods, high performance nanoscale modulators, detectors, multiplexers and demultiplexers, architecture for addressing ultradense systems, techniques for efficient high capacity/bandwidth I/O of data to and from the chip.

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	FY 2005	FY 2006	FY 2007
Maskless Direct-Write Nanolithography for Defense Applications	0.000	0.000	21.000

(U) This program will develop a maskless, direct write lithography tool that will address both the DoD’s need for affordable, high performance, low volume Integrated Circuits (ICs) and the commercial market’s need for highly customized, application-specific ICs. In addition, this program will provide a cost effective manufacturing technology for low volume NanoElectroMechanical Systems (NEMS) and Nano Photonics initiatives within the DoD.

(U) Maskless lithography tools, installed in the Trusted Foundry and in commercial foundries, would enable incorporation of state-of-the-art semiconductor devices in new military systems, and allow for the cost-effective upgrade of legacy military systems.

(U) Program Plans:

- Develop a maskless, direct write lithography tool that will address *both* the DoD’s need for affordable, high performance, low volume ICs and the commercial market’s need for highly customized, application-specific ICs.
- Determine a cost effective manufacturing technology for low volume NanoElectroMechanical Systems (NEMS) and Nano Photonics initiatives within the DoD.
- Enable incorporation of state-of-the-art semiconductor devices in new military systems, and allow for the cost-effective upgrade of legacy military systems.

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	FY 2005	FY 2006	FY 2007
Stand-off Detection and Identification	0.000	0.000	6.000

(U) The Stand-off Detection and Identification program will detect and identify explosive threats at a stand-off distance, which is critical to force protection in all military operations, especially in urban scenarios. Multiple techniques will be available for detection, but no single technique provides both high probability of detection with low false alarm rate, and identification of specific characteristics of the threat. A micro-system approach with multiple, synergistic sensor technologies integrated in a compact package, will be critically needed for wide spread deployment of this sensor capability.

(U) The microsystem approach involves the identification of significant attributes from multiple non-over-lapping perspectives, such as shape and chemical signature, at stand-off ranges of fifty meters to potentially one hundred meters. This presents major challenges in imaging through opaque media; identification of signatures in parts per billion in high background ambient; selection of specific wavelength bands of interest; and the signal / imaging processing required for positive identification. The system configuration presents additional integration challenges for potential application in manportable systems or small autonomous vehicles.

(U) Program Plans:

- Develop unique imaging techniques suited to imaging through visually opaque objects at a stand-off distance.
- Investigate multiple imaging approaches, including integration of typically disparate techniques such as passive infrared and radio frequency with active techniques, such as laser imaging and high energy active imaging techniques, such as x-ray imaging.
- Implement x-ray imaging and develop compact package for remote vehicle applications. X-ray source requirements, such as power, size, weight, focal spot, tube configuration, including various beam formation techniques, must be investigated to efficiently transmit radiation over the stand-off distance. Source requirements will be traded-off for more efficient sensor technology, notably two dimensional arrays of cadmium telluride or silicon carbide with high spatial resolution.
- Identify particular effluents, which requires development of unique spectrometer-on-a-chip sensor concepts that cover a broad spectral range.
- Investigate excitation sources and tunable sensors from the far-infrared through millimeter wave spectral regions.

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- Address issues including efficient radiation coupling into the sensor; spectral selectivity; signal enhancement techniques.

	FY 2005	FY 2006	FY 2007
Deep Ultraviolet Avalanche Photon Detectors	0.000	0.000	5.000

(U) Recent advances in Wide Bandgap Semiconductor materials have opened new possibilities for exploiting the ultra-violet region of the electromagnetic spectrum. The current Semiconductor Ultra Violet Sources (SUVOS) program has been successful in advancing the state of the art of Ultra Violet (UV) light emitting diodes and laser diodes. This follow-on program seeks to develop high sensitivity, compact ultra violet detectors. Specifically, avalanche photodiodes will be developed that can detect single photons. These UV detectors will dramatically improve the performance and reduce the size and weight of the biological warning detectors under development in the SUVOS program. They will also increase the range and data rate of covert UV communications systems.

(U) Program Plans:
- Develop high sensitivity, compact ultra violet detectors.
- Develop avalanche photodiodes that can detect single photons.
- Improve the performance and reduce the size and weight of the biological warning detectors under development in the SUVOS program.
- Reduce the defects by orders-of-magnitude and develop highly doped cladding layers.
- Optimize the detector response and switching speed.

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	FY 2005	FY 2006	FY 2007
WIFI-EYEPOD	0.000	0.000	6.000

(U) The WIFI-EYEPOD program will transform the dismounted soldier into a semi-autonomous DC - 10 GHz sensor/comms/SIGINT platform using a personal digital assistant (PDA) modified with a broadband multifunctional RF sensor plugged into its universal serial bus (USB) port. Combined with the current DARPA STAP-BOY program, or even a standard laptop, the RF EYEPOD enhancement will enable real-time local processing for extremely time-sensitive and perishable data requiring immediate processing and response. The WIFI-EYEPOD RF sensor may be used to control and or hunt near field enemy WIFI and communications networks allowing the soldier to virtually see enemy combatants communicating and setting up attacks, hiding behind walls and in buildings mixed with non-combatants. Working in small networks will permit instantaneous location(s) of sniper fire and gunfire for retribution, and positions of tactical squad members relative to inside and outside of buildings, without detection by enemy sensors.

(U) In addition to adding RF-sensory and networking capability to PDAs and vehicle-mounted information processing hardware, the WIFI-EYEPOD will provide secure communications and networking capability so that the processed information can be compressed and downloaded realtime to larger, holistic sensor integration systems, providing micro-detail to create macro understanding at the unit and division command levels. Transition targets are through Army PM soldiers systems and USMC ground forces.

(U) Program Plans:

- Develop, integrate and optimize diverse system capabilities into a single low cost miniature package. With the cost target at less than $1K per unit, WIFI-EYEPOD RF sensor together with embedded graphics processor technology enables plug and play widespread adoption by all dismounts.
- Optimize commercial integrated circuits in wideband digital synthesizers, and custom high dynamic range Analog/Digital Converters (ADC's) and digital filters into a mixed-signal Analog Signal Integrated Circuits (ASIC) using the latest processes in SiGe and 90nm CMOS, and integrate a modem, quad-band antenna, and Ultra-Wide Band (UWB) antenna and transmitter with commercial interface to an embedded processing unit.

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	FY 2005	FY 2006	FY 2007
MEMS Electronic & Photonic Integrated Circuits in Silicon	5.000	10.000	5.000

(U) This program will provide new systems capabilities for integrated RF microsystems by developing material and device processing technologies for integrating microelectromechanical RF structures (MEMS) with integrated RF/microwave/millimeterwave (MMWAVE) electronics to form reconfigurable, multi-functional active RF surfaces. The integration of massive numbers of miniaturized MEMS structures with advanced control and RF processing will enable fully programmable metallic and active RF processing surfaces which will be capable of rapid reconfiguration under electronic control to adapt their resonant and out-of-band characteristics, creating new classes of components that can rapidly and efficiently span electromagnetic bands with high signal-to-noise ratio and minimal losses. These highly integrated active RF elements will consist of efficient, low loss, low power, agile transceivers with high speed digital RF memories, precision analog/mixed signal circuits, and MEMS sensors and structures for actively reconfiguring the resonant structures and devices.

(U) Program Plans:

- Develop and demonstrate fabrication technologies for critical high performance electronics and micromachined components with very high quality factors and high performance radio-frequency characteristics compatible with integration into active radio frequency surfaces.
- Develop and demonstrate chip and device-scale electromagnetic isolation approaches.
- Complete development of scaled fabrication process for reducing power and insertion loss of integrated radio-frequency components.
- Complete measurements of radio-frequency parameters of integrated radio-frequency components and perform de-embedding analysis.
- Demonstrate integration technologies that result in the ability to combine high speed analog/mixed signal electronics with digital control devices and with micromachined devices to form active surfaces for agile radio-frequency microsystems.
- Develop control algorithms for controlling the active electronics and micromachined components across wide dynamic range and bandwidth for active radio-frequency surface applications.
- Complete far-field and power measurements of fully programmable radio-frequency active surface microsystem.

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	FY 2005	FY 2006	FY 2007
3-D Imaging Technology Development	1.000	0.000	0.000

(U) The 3-Dimensional Imaging Technology Development program developed new high speed imaging devices and array technology with high resolution three dimensional images of tactical targets at ranges of 7 to 10 kilometers, with increased identification range of tactical targets, especially from fast moving platforms.

(U) Program Plans:
- Demonstrated range imaging at the eye-safe wavelength of 1.54 micrometers with a minimum array size of 64 x 64.

	FY 2005	FY 2006	FY 2007
Embedded Intelligent Migrating Symbolic Constructs	2.936	0.000	0.000

(U) Program Plans:
- Developed technologies for embedded intelligent microsystems.

	FY 2005	FY 2006	FY 2007
Novel Crystal Components for Imaging and Communications	1.000	0.000	0.000

(U) The goal of this program was to develop novel imaging technologies utilizing infrared (IR) and crystal growth approaches.

(U) Program Plans:
- Continued the development of novel crystal components.

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	FY 2005	FY 2006	FY 2007
Electronic Miniaturization	0.000	5.100	0.000

(U) Program Plans:
- Develop novel techniques for miniaturization of electronic components.

	FY 2005	FY 2006	FY 2007
Small Scale Systems Packaging	0.000	1.000	0.000

(U) Program Plans:
- Develop new approaches for packaging of small electronic components.

	FY 2005	FY 2006	FY 2007
Advanced Lithography Fabrication Processing	0.000	2.550	0.000

(U) Program Plans:
- Develop new fabrication processing in lithography systems.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	213.971	213.316	232.489	238.395	245.796	248.154	253.154
Command & Control Information Systems CCC-01	54.978	55.485	56.935	56.530	56.900	56.900	55.900
Information Integration Systems CCC-02	93.645	108.384	93.903	93.560	96.795	98.795	103.795
Classified CCC-CLS	65.348	49.447	81.651	88.305	92.101	92.459	93.459

(U) Mission Description:

(U) This program element is budgeted in the Advanced Technology Development Budget Activity because its purpose is to demonstrate and evaluate advanced information systems research and development concepts.

(U) The goals of the Command and Control Information Systems project are to develop and test innovative, secure architectures and tools to enhance information processing, dissemination and presentation capabilities for the commander. This will give the commander insight into the disposition of enemy and friendly forces, a joint situational awareness picture that will improve planning, decision-making and execution support capability and provide secure multimedia information interfaces and assured software to “on the move” users. Integration of collection management, planning and battlefield awareness programs is an essential element for achieving battlefield dominance through assured information systems.

(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. The principal element of this project is assured communications using standard and non-traditional means.

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

	FY 2005	FY 2006	FY 2007
Previous President's Budget	219.765	216.408	220.918
Current Budget	213.971	213.316	232.489
Total Adjustments	-5.794	-3.092	11.571
Congressional program reductions	-0.169	-3.092	
Congressional increases	0.000		
Reprogrammings	0.000		
SBIR/STTR Transfer	-5.625		

(U) Change Summary Explanation:

FY 2005	Decrease reflects DOE transfer for P.L. 108-447 and SBIR/STTR Transfer.
FY 2006	Decrease reflects undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Increase reflects emphasis on classified programs in the Command, Control and Communications Systems Program Element.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Command & Control Information Systems CCC-01	54.978	55.485	56.935	56.530	56.900	56.900	55.900

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

(U) Military operations since the end of the Cold War illustrate that current theater-level command, control, communications, and intelligence/information systems lack the ability to fully support operations in complex, time-critical environments. Warfighters must be prepared for operations ranging 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 or the ability to orchestrate high-tempo planning, rehearsal, and execution. The programs in this project are developing and testing innovative, secure architectures and tools to enhance information processing, dissemination, and presentation capabilities. The programs provide 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, as well as secure multimedia information interfaces and software assurance to the warfighter "on the move." Integration of collection management, planning, and battlefield awareness are essential elements for achieving battlefield dominance through assured information systems.

(U) Warfighter dependence on information systems is growing. DoD systems must deliver and protect information and assure the availability of associated services – particularly in a stressed environment. Included in this project are Joint Air/Ground Operations: Unified Adaptive Replanning (JAGUAR), Advanced Ground Tactical Battle Manager, Predictive Battlespace Awareness, Comprehensive Force Protection, Urban Commander, Heterogeneous Urban Reconnaissance Team (HURT), Tactical Group Decision Analysis Support System, Dynamic Airspace Allocation, Predictive Analysis for Naval Deployment Activities (PANDA), and Organically Assured and Survivable Information Systems (OASIS).

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(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Joint Air/Ground Operations: Unified, Adaptive Replanning (JAGUAR)	10.936	10.178	10.356

(U) The Joint Air/Ground Operations: Unified, Adaptive Replanning (JAGUAR) program will improve battle management for complex air campaigns that employ new air platforms featuring precision sensors, weapons and communications relays. The JAGUAR system is driven by: 1) targeting information, both for sensor targets and strikes, expressed as point and area targets (i.e., search, combat air patrol); 2) rules of engagement and procedural constraints, such as airspace restrictions; and 3) availability of platforms, weapons, sensors, and communications equipment. From this information JAGUAR produces ingress routes, flight schedules and patrol zones, while assuring airspace and electronic deconfliction. The technology provides pilots and commanders the option to choose conventional tactics or conceive unconventional operations. In the latter case, the system captures the innovation and retains the strategic maneuver for future mission plans. JAGUAR monitors actual plan execution against expected results and alerts commanders to significant differences. The technology captures statistical descriptions of small differences to help assess the robustness of future plans. There is a Memorandum of Understanding in place with the U.S. Air Force and technology transition is planned to occur by FY 2008.

(U) Program Plans:
- Equip a training facility with software tools and human observers to capture plans as constructed, executed, and modified.
- Conduct exercises and capture a large set (several hundred) of mission plans as example cases.
- Decompose each plan into plan fragments.
- Assemble groups of related plan fragments into plan templates.
- Develop a large-scale integration algorithm to assemble plan fragments into a synchronized operational plan.
- Build optimization tools to tailor routes, schedule events, and deconflict airspace and radio frequencies.
- Compile standard mission plan products from the optimized operational plan.
- Demonstrate tools to correlate actual field events to planned events.
- Evaluate these techniques in periodic training events

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	FY 2005	FY 2006	FY 2007
Advanced Ground Tactical Battle Manager	11.070	9.220	6.133

(U) The Advanced Ground Tactical Battle Manager program is developing automated decision support tools for Army and Marine tactical commanders at the battalion level and below. The program also provides support for combined operations employing dismounted soldiers, manned platforms, and autonomous vehicles. The tool will elicit skeletal courses of action through a graphical interface with unit commanders and extend plans by applying adversarial reasoning techniques to identify vulnerabilities and opportunities in the predicted enemy course of action. Finally, modifications or counteractions will be developed to reduce vulnerabilities. A variant of the program would issue plans to subordinate unit commanders and human controllers and possibly integrate necessary elements to automated platforms or automated battle managers. The technology is planned for transition to the Army.

(U) Program Plans:

- Predict enemy movements 30 minutes into the future.
- Identify aggressive and timid enemy behaviors.
- Identify potentially deceptive behaviors.
- Extend prediction horizon further into the future.
- Include concealment and deception behaviors in predictions.
- Build interfaces to existing and future Army intelligence and command and control systems.
- Continue to conduct experiments to ascertain the value of the tools.

	FY 2005	FY 2006	FY 2007
Predictive Battlespace Awareness	4.034	4.046	2.258

(U) The Predictive Battlespace Awareness program develops technology to predict the range of an opponent's future actions. The program will enable commanders to pre-position sensors, weapons, and information to counter the opponent's actions. The program will develop model-

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and knowledge-based techniques to predict areas of operation and tactical objectives. The technology will support the modeling of courses of action ranging over time horizons from hours to days. Program techniques permit "on-the-fly" tailoring of models and contextual knowledge and leverage knowledge of sensor effectiveness, mobility factors, tactical templates, and target characteristics. Techniques to be developed include variable-fidelity prediction, such as the ability to determine both target locations over minutes and force zones of influence over hours. The tools anticipate enemy operations in time to thwart them with effects-based targeting, enabling use of sensors and other resources in proactive modes. The program empowers commanders to avoid canned responses and supports rapid incorporation of insights about new enemy strategies, capabilities, and tactics from peacetime to the heat of battle. The program will significantly enhance today's mostly manual, slow planning, and analysis processes. Technologies are planned to be transitioned to the Air Force Distributed Common Ground Station.

(U) Program Plans:
- Survey recent military operations to identify cases where opponent's actions could have been anticipated.
- Define a set of realistic challenge problems, including scenarios and a simulation facility to illustrate the context and value of predictive battlespace awareness.
- Develop approaches to prediction that combine physics-based modeling (e.g., for mobility and observability) with knowledge-based techniques (e.g., plan generation or recognition).
- Evaluate alternative approaches against the challenge problems.
- Define a system architecture that combines the best approaches into a consistent, mutually supporting toolkit.
- Integrate selected technologies into the toolkit.

	FY 2005	FY 2006	FY 2007
Comprehensive Force Protection	4.224	4.943	3.763

(U) The Comprehensive Force Protection program is developing a rapidly deployable system to provide assured protection of permanent or temporary U.S. base camps in hostile territory. The system includes wide-area sensors and platforms to maintain continuous surveillance of the camp area. The sensors detect potential intruders and weapon launches. The program also includes a suite of airborne sensor platforms that can be tasked rapidly to investigate potential threats or "lock on" to personnel or weapons involved in an attack. Data collected from sensors is

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automatically analyzed, correlated, and provided to commanders to confirm threats and authorize precision weapons to engage. The system maintains continuous perimeter surveillance, allows rapid investigation, and, when authorized, attacks threats. Technologies are planned to transition to the U.S. Army.

(U) Program Plans:
- Review past and forecasted threat analyses to characterize intrusions, events, activities and signatures.
- Select a test area in which data on intrusions can be collected.
- Place a variety of sensors, both extant and developmental, into the test site along with a communications network back to a data analysis and command station.
- Collect data on realistic intrusions in a variety of weather conditions.
- Characterize the performance of candidate signal processing, target recognition and localization, and environment monitoring algorithms on the test data.
- Select a set of algorithms for a baseline system build.
- Construct and calibrate a system performance model for the selected algorithms.
- Exercise the baseline system in the testbed and compare results against the performance model.
- Selectively improve algorithmic components that contribute the most to performance gaps.
- Demonstrate the final system in continuous operation at a CONUS base.

	FY 2005	FY 2006	FY 2007
Urban Commander	14.795	14.025	11.727

(U) The Urban Commander thrust develops automated tools to help ground commanders construct detailed, realistic operational plans, particularly in nontraditional and urban environments. Partial plans are represented in hierarchical task networks and visualized through synchronization matrices, icon overlays, or tactical sketch animations. Commanders and staff modify, refine, and extend a plan through voice, sketching, and semi-structured input. The system links fragments constructed at different sites, transfers information among related parts, and discovers and recommends solutions for inconsistencies. The system continuously compiles a set of plan cases and employs analogical matching

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to propose extensions to current plans suggested by past experience. Plan elements are communicated through an integrated set of protocols from the unit commander down to dismount commanders equipped with advanced heads-up displays and helmet-worn sensors. Finally, the program continuously assesses progress against the operational plan and alerts users to significant deviations.

- The Multi-spectral Adaptive Networked Tactical Imaging System (MANTIS) program develops, integrates, and demonstrates a soldier-worn visualization system. Both helmet-mounted and handheld versions will be built during Phase 3 of the program. The system consists of five elements: 1) multi-spectral sensor suite; 2) high resolution digital display; 3) inertial measurement unit (IMU); 4) high-speed processor; and 5) power supply. MANTIS provides the warfighter with digitally-fused imagery in real time from the multi-spectral sensor suite, exploiting three distinct spectral bands: 1) the Visible/Near Infrared (VNIR, .4 - .9 microns); 2) the Short Wave Infrared (SWIR, 1 - 2 microns); and 3) the Long Wave Infrared (LWIR, 8 - 12 microns). The fused imagery is shown on two displays; one has a wide field-of view and the other a narrow field-of-view. When viewed together the system furnishes a larger field-of-view image with simultaneous high resolution and stereo capability. The system also allows the warfighters to record and "play back" the video while on the battlefield. The record/playback feature includes: electronic zoom, scroll, pan and panoramic image stitching. MANTIS provides a vision-aided inertial navigation system (INS) and will interface with the future soldier's global positioning system (GPS). When combined with precise pose estimation from the helmet-mounted IMU, MANTIS allows battlefield information to be overlaid on the display to provide increased situational awareness. MANTIS interfaces with the future soldier's advanced communications and networking systems, allowing the warfighter to send/receive video images and position information with fellow soldiers and commanders in real time. The coupling of the imaging system with INS/GPS will provide the individual warfighter a "point-click-kill" capability for real-time target hand-off capability to networked smart weapons fired from remote locations, thereby significantly increasing the lethality of the individual warfighter. The MANTIS technology is planned for transition to the Army at the conclusion of Phase III anticipated to be completed early in FY 2008.

- An urban warfare environment presents the warfighter with limited sightlines and mobility with insufficient knowledge of the disposition of enemy combatants, civilians, and occupied structures. As a result, the warfighter requires situational awareness information, presented in a manner that accounts for current operational context and personal strengths, limitations, and preferences. The Urban Commander program develops planning and control tools tailored to dismounted operations in complex urban environments. "On-the-ground" warfighters do not have time to constantly check an information rich visual display. Cognitive Impedance Matching (CIM) technology will develop a prototype system for presenting the information at the correct time and format to the affected individual. The system will

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ensure that situational awareness will be obtained and maintained across a range of echelons and battlefield conditions. Urban Commander forms a command and control substrate that enables ground forces, including vehicles and dismounts, to rapidly coordinate actions as the situation and commanders knowledge of the situation change. The program includes: 1) spatial analysis to determine lines of sight and fields of fire; 2) planning aids to assist in sensor placement and route planning; 3) visualization tools to allow commanders and soldiers to rapidly apprehend and address a situation; and 4) analysis tools to suggest locations and types of potential threats. Urban Commander technologies are planned to transition to the Army Program Executive Office Command, Control, and Communications Tactical (PEO C3T).

(U) Program Plans:

– Multi-spectral Adaptive Networked Tactical Imaging System (MANTIS)
  - Delivered Short Wave Infrared (SWIR) sensor assemblies for evaluation.
  - Completed independent laboratory characterization/field tests on SWIR sensors.
  - Completed system design analyses.
  - Developed fully functional MANTIS testbed (helmet-mounted sensor suite and off-board processor).
  - Evaluate/demonstrate multi-sensor imagery and processing capability via MANTIS testbed.
  - Complete functional prototype design.
  - Fabricate three MANTIS functional prototypes (two helmet-mounted, one handheld) for evaluation.
  - Conduct independent laboratory/field tests of MANTIS prototypes.
  - Transition to the US Army (PEO Soldier).

– Urban Commander
  - Identify a set of urban combat scenarios ranging from peacekeeping to aggressive assault and document sets of mission tasks from which tactical plans may be constructed.
  - Define a common plan representation, based on service training material, for combined arms operations and construct an initial collection of operational plans, for many scenarios and force structures.
  - Develop multi-modal presentation of situation awareness data, utilizing visual, auditory, haptics, and other presentation modes.
  - Develop new interfaces for presenting content rich information in a compact format and operational languages.

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- -- Construct protocols to propagate changes generated at one location to affected locations, in accordance with defined policy and build flexible algorithms to match changes received from remote locations to the aspects of a plan retained locally.
- -- Demonstrate detection of plan inconsistencies and recommend corrections and conduct a series of laboratory evaluations with Army and Marine commanders to assess the quality and utility of program products.
- -- Develop an architecture based on the concept of a tactical global information grid (T-GIG), a service-oriented architecture that provides adaptive user filtering at the GIG side (not the user side) for information delivery, fault tolerant mechanisms, and controlled filter propagation.
- -- Develop a context aware system, incorporating sensors and software to detect the warfighter's operational conditions and current cognitive state, and to detect if the warfighter has incorporated the situation awareness data that has been presented.
- -- Incorporate additional tools for presenting and understanding situation awareness, including mapping and line of fire tools.

	FY 2005	FY 2006	FY 2007
Heterogenous Urban Reconnaissance Team (HURT)	9.100	10.220	5.782

(U) The Heterogeneous Urban Reconnaissance Team (HURT) initiative develops integrated tactical planning and sensor management systems for heterogeneous collections of unmanned platforms operating in urban environments. HURT employs a model-based control architecture with dynamic teaming and platform-independent command and control. The system registers new platforms with the battle manager (kinematics, maneuverability, endurance, payloads, and communications links) to facilitate platform-independent tasking. HURT provides a commander's interface that allows collaborative tasking of the platforms in the form of operational missions, such as search, track, identify, or engage, rather than routes and events. Additionally, it supplies computationally intensive decision aids, such as advanced 4D airspace and groundspace deconfliction tools, route planners, and task/platform assignments algorithms. The technology presents mission status and future courses of action to commanders for collaborative adjudication. HURT enables augmentation of low-footprint, rapidly deployable, easily sustainable human command structures with teams of machines operating together. HURT technology is planned for transition to the United States Marine Corps, U.S. Special Operations Command, and Air Force Special Operations Command at the conclusion of Phase II anticipated to be completed by FY 2007.

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(U) Program Plans:
- Select a baseline planning/control algorithm.
- Develop a centralized information management server.
- Define multi-user reconnaissance missions.
- Assess the ability of the planning/control algorithms to effectively use each platform.
- Conduct field tests at an urban warfare training facility.

	FY 2005	FY 2006	FY 2007
Tactical Group Decision Analysis Support System	0.000	2.853	4.591

(U) The Tactical Group Decision Analysis Support Systems program will develop distributed group decision analysis tools. These tools will increase the tempo of the tactical commander's observe-orient-decide-act (OODA) loop, the quality of decisions, and contribution of data point input across the organization with an emphasis on maximizing input on decisions breadth, decision content, problem attributes considered, and events/actions considered. The developed tools will be applied in crisis management situations for tactical commanders and could be transitioned to existing emergency response command and control systems as well as emerging tactical command and control systems. The technologies developed under this program are planned for transition to the Services in FY 2008.

(U) Program Plans:
- Develop novel data structures and algorithms to exploit as many individual contributions as possible to a group decision problem in order to provide a comprehensive and well-founded automated decision.
- Create distributed infrastructure and user interface mechanisms to support real-time group decision analysis without the need for expert facilitators/participants to be in the same place at the same time.
- Provide a capability for continuous tracking of real-world events as well as stakeholder revisions related to the decision, to alert the tactical commander when the decision that was made is no longer optimal.
- Develop prototype decision analysis systems and validate that these systems lead to more effective decision making.

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	FY 2005	FY 2006	FY 2007
Dynamic Airspace Allocation	0.000	0.000	2.500

(U) The goal of the Dynamic Airspace Allocation program is to maximize airspace utilization supporting global operations of military and civilian aircraft through dynamic airspace allocation. The labor-intensive human centric process will be replaced by an automated system that addresses all objects in the airspace to include munitions, manned aircraft, and unmanned air vehicles. The automated system will be developed to be compliant with Federal Aviation Administration (FAA) and International Civil Aviation Organization (ICAO) regulations to allow utilization of the system in peace time and war. Challenges to be addressed include maintaining real-time kinematic information for all objects in the airspace and the development of algorithms to dynamically reallocate airspace without human involvement.

(U) Program Plans:
- Develop and simulate potential system architectures.
- Develop a preliminary design for the system.
- Demonstrate critical technologies.
- Develop and test a prototype system.

	FY 2005	FY 2006	FY 2007
Predictive Analysis for Naval Deployment Activities (PANDA)	0.000	0.000	9.825

(U) Predictive Analysis for Naval Deployment Activities (PANDA) develops technology to automatically learn normal activity models (motion and emission) for maritime surface vessels, automatically detect anomalous behavior, provide context modeling to resolve known categories of anomalies (e.g., due to weather and business rule changes), and alert processing. The resulting technology can be extended and applied to a wide range of applications including ground vehicles, troop movements, and individual targets of interest (e.g., suspected insurgents), as the methods of tracking those targets improves. The initial application will be anomaly detection in the maritime domain. PANDA technologies are planned to transition to the Office of Naval Intelligence and the Fleet Commanders.

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(U) Program Plans:

- Develop new technologies and system architectures to support distributed learning of activity pattern models from complex spatio-temporal, all-source data.
- Demonstrate that individual and class-of-vessel motion-based activity patterns can be learned and used to detect anomalies.
- Use patterns to predict movements and classify (groups of) vessels as potentially (non) hostile with a low incidence of false alarms.
- Learn and detect multi-ship correlated activities.
- Incorporate context models.
- Leverage detection/tracking capabilities to include large and small (harbor) vessels.

	FY 2005	FY 2006	FY 2007
OASIS	0.819	0.000	0.000

(U) The Organically Assured and Survivable Information Systems (OASIS) program developed technologies for DoD information systems to sustain the operation of mission-critical functions in the face of cyber attacks or accidental faults. These technologies included an intrusion tolerant database architecture using commercial off-the-shelf (COTS) components; a distributed architecture for deploying intrusion-tolerant mechanisms featuring explicitly stated but flexible tolerance policies; a framework for tolerating intrusions in large-scale, heterogeneous, networked computing enterprises; and a system integrity and availability framework that combines passive intrusion tolerance and active intrusion recovery mechanisms. The program used the systems approach to the intrusion problem by integrating prevention, detection, response and tolerance technologies into a military system. The goal was to significantly improve the survivability of the system in the face of a large-scale cyber attack. The OASIS technology is transitioning to the Air Force after completion of red team validations. Specifically, key aspects of the survivable design are planned to be incorporated to the Joint Battlespace Infosphere (JBI) system development.

(U) Program Plans:

- Integrated OASIS and other DARPA and commercial technologies to develop and demonstrate a survivable variant of the Joint Battlespace Infosphere.
- Validated survivability claims of OASIS researchers technologies using recognized methodologies on operational systems.

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- Demonstrated the effectiveness of survivable architectures in the face of a determined cyber attack on an exemplar critical military information system.
- Evaluated and applied novel approaches to composing assurance cases for large-scale systems.
- Validated the survivable system with a comprehensive adversarial test scenario.
- Probed the extent of enhanced survivability capabilities with a series of red team experiments.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Information Integration Systems CCC-02	93.645	108.384	93.903	93.560	96.795	98.795	103.795

(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 to enable true network centric warfare concepts. This project hosts many of DARPA's most innovative communications and networking systems. Programs funded are: the Secure Adaptive Waveforms (SAW) program, the Connectionless Networking (CN) program, the Next Generation (XG) program, the Advanced Speech Encoding (ASE) program, the Symbiotic Communications (SYCO) program, the Optical & RF Combined Link Experiment (ORCLE) program, the Policy Based Network Management program, the Disruption Tolerant Networking program, the Network Centric Operations/Battle Command program, the Advanced Antenna Concepts program, the Fiber-Optical Network for Aerospace Platforms program (formerly the Navy Photonics Program), the Advanced HF Communications program, the Communications to the Tactical Edge program, the Self-Forming Networks program, the Scalable MMW Architectures for Reconfigurable Transceivers (SMART) (formerly Ideal RF Link) program, the DARPA Interference Multiple Access Communications (formerly Robust, Responsive, Reconfigurable and Invisible (R3I) Network) program, the Terabit Optical Ethernet program, the Multiple-Input/Multiple-Output (MIMO) Satcom program, and the Wireless Network after Next (WNaN) program.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Secure Adaptive Waveforms	6.356	4.013	3.127

(U) The Secure Adaptive Waveforms (SAW) program, and the related Polarized Rotation Modulation (PZRM) Communications program, addressed lessons learned from the Airborne Communication Node (ACN) program concerning the need for secure communications waveforms. The SAW program investigated approaches for an adaptive waveform agile communications system that could change structure (frequency,

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modulation, data rate, hop rate, code, etc.) on a periodic or aperiodic basis to minimize the probability of detection, interception, and exploitation in order to support covert operations.

(U) The goal of the Polarized Rotation Modulation (PZRM) Communications program is to develop new extremely high data rate, point-to-point, and wireless communications using the PZRM communications concept which can be implemented at any wavelength – RF to visible – to exploit the presently unused polarization and rotation dimensions of radiation. The PZRM communications program will investigate the use of polarization modulation and the ability for conventional radios to carry all information over the transmitted signal amplitude, phase and frequency. Polarization modulation introduces an additional dimension. A radio with four polarization possibilities would transmit four times the information with all other aspects of the waveform held constant. Use of the antenna as part of the information processing architecture of a radio has not been previously performed. This technology will greatly increase the capability of existing channels without increase in spectrum or modem complexity. The program will be demonstrated as an enhancement to an otherwise state of the art networking system. The Polarization Modulation technology is planned for transition to Service applications in FY 2008.

(U) Program Plans:

- Secure Adaptive Waveforms
  - Initiated system design effort.

- Polarized Rotation Modulation Communications
  - Perform simulations to determine bit error rates and the optimum modulation schemes commensurate with the center frequencies and bandwidth permissible.
  - Conduct simulations to verify performance predictions and identify component elements.
  - Construct a demonstration prototype and undertake laboratory tests to validate PRZM concept.
  - Demonstrate at long range under operational conditions.

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	FY 2005	FY 2006	FY 2007
Connectionless Networking (CN)	7.101	5.707	3.580

(U) In order to bring data efficiently from high value, but energy limited sensors (such as unattended ground sensors (UGS)), into system architectures like that of the Airborne Communications Node (ACN), a new fundamental emphasis must be placed on how these kinds of sensor networks communicate. The Connectionless Networking (CN) program will develop technology to allow networks (such as UGS) to send and receive messages without initial link acquisition or previous sharing of routing information. This will improve energy per bit of delivered information by as much as 100 to 1,000 times compared to conventional and near-term deployable communications systems such as currently contemplated by both commercial and military users. Conventional radio link and network designs expend most of the energy on link establishment and maintenance, as well as packet and network overhead. This energy requirement not only limits the lifetime of energy-limited systems, it unnecessarily fills the radio spectrum; limiting available bandwidth; creates unnecessary risks of detection; and increases thermal loads. These impacts are especially severe for communications with proliferated sensors, or remotely operated weapons. Eliminating the requirement to maintain a continuous network link would enable these platforms to provide continuous connectivity without consumption of power, or compromising emanations. The CN program will exploit existing and available signal processing components, intelligent (processing and memory intensive) routing, and availability of situational information to demonstrate a total energy savings of at least 100 times typical connection oriented network applications. The Connectionless Networking technology is planned for transition to the Army, Navy, and Air Force for unattended ground sensors and low duty cycle applications in FY 2007.

(U) Program Plans:
- Investigated specific technology requirements for each of the traditional wireless networks.
- Determined layer specific solutions.
- Investigated layer integrating approaches.
- Modeled acquisition and media access; network and transport design; and aggregate energy cost savings.
- Predicted achievable performance improvement.
- Translate the technology design and simulations into actual hardware and software.
- Design and fabricate prototype CN network node devices, and perform laboratory and field CN demonstrations.

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- Develop and evaluate candidate approaches for implementation complexity, on-board processor and memory capability/power, overhead, scalability and performance.

	FY 2005	FY 2006	FY 2007
Next Generation (XG)	15.571	10.916	2.869

(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 dynamic spectrum access. 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 access to the spectrum, the technologies and subsystems that enable dynamic access, and the system 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 a set of standard dynamic spectrum adaptation technologies for legacy and future emitter systems for joint service utility. The XG Communications technology is planned for transition to the Army in the Joint Tactical Radio Systems clusters in FY 2007.

(U) Program Plans:

- Conducted CONUS and OCONUS spectrum usage analysis.
- Analyzed military bands during force exercises.
- Analyzed civilian band usage in a variety of locales (urban and rural settings).
- Analyzed correlation between distributed nodes.
- Investigated concepts for employment and utility of a dynamic waveform to the warfighter.

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– Conducted lab demo of “sense and adaptation” performance.
– Performed analysis and simulation of multiple control protocols.
– Used military band spectrum analysis to assess subsystem technology development.
– Develop and evaluate candidate approaches for implementation complexity, on-board processor and memory capability/power, overhead, scalability and performance.
– Develop hardware prototypes.
– Demonstrate spectrum agility performance of prototypes in field experiments.

	FY 2005	FY 2006	FY 2007
Advanced Speech Encoding (ASE)	4.782	6.699	5.383

(U) The Advanced Speech Encoding (ASE) program will achieve an order of magnitude reduction of voice communication bit rates in noisy military environments over current state-of-the-art voice encoders (VOCODER). Such a reduction will significantly decrease the probability of detection of transmitted signals and will also decrease the required transmit energy, thereby increasing battery lifetime. The program will pursue two novel approaches toward achieving its goal. One approach builds upon multiple noise-immune sensors that have been combined with traditional coding algorithms to achieve significant improvements in intelligibility and quality in harsh noisy environments at 2400 bits per second (bps). This approach will be extended to nontraditional ultra-low-bit-rate coding algorithms in order to achieve 300 bps coding capability in harsh military environments. Alternative approaches will also be explored, such as the communication without acoustic information achieved by extracting laryngeal and sublingual muscle signals that are produced when a person generates sub vocal speech. This approach will yield a revolutionary capability in situations where stealth is of the utmost importance, or in situations where acoustic signals cannot be used, such as under water. The Advanced Speech Encoding technology is planned for transition to the Army by FY 2008.

(U) Program Plans:
– Demonstrated significant improvement of intelligibility and quality voice communications in harsh noisy environments at 2400 bps.
– Demonstrate a voice communication system (sensors plus coder) operating at 1000 bps that is at least as good as today’s DoD standard in harsh military noisy environments.

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- Demonstrate a 300 bps VOCODER with intelligibility, quality and aural speaker recognition in harsh military noisy environments that is at least as good as today's DoD standard.
- Demonstrate the capability for ultra-low-rate coding in a field demonstration of a prototype communications system.
- Explore the nature of sub vocalic signals (physiological source, speaker dependence, robustness) and the information content of the signals.

	FY 2005	FY 2006	FY 2007
Symbiotic Communications (SYCO)	12.726	8.738	1.375

(U) The Symbiotic Communications (SYCO) program will develop an airborne passive radar system to enable precision targeting and battlefield situational awareness. SYCO will generate high resolution Synthetic Aperture Radar (SAR) imagery. This system will operate passively and be effective in clear and adverse weather. SYCO has demonstrated a proof-of-concept through ground-based and airborne flight tests. Additionally, a design for a real-time prototype, as well as automated algorithms to enable real-time processing have been developed and tested. To complete this project, the prototype will be developed and packaged to be form/fit/function compatible for transition. The SYCO technology is planned for transition for Service applications in FY 2008.

(U) Program Plans:

- Develop real-time airborne demonstrator system.
- Demonstrate high resolution SAR at national imagery interpretability rating scale level 4.
- Participate in limited user testing.

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	FY 2005	FY 2006	FY 2007
Optical & RF Combined Link Experiment (ORCLE)	23.018	21.041	10.597

(U) The Optical & RF Combined Link Experiment (ORCLE) seeks to develop combined radio frequency (RF) & free space optical (FSO) communications as well as networking technologies that exploit the benefits of complementary path diversity. This effort will demonstrate improved battlespace communications using a hybrid RF and FSO link in air-to-air-to-ground environments. The central challenge is to enable optical communications bandwidth without giving up RF reliability and “all-weather” performance. ORCLE will develop RF and FSO propagation channel analysis, coding techniques and modeling to include weather, atmospherics and aero-optics to provide the joint force commander assured high-data rate communications. The technical objective is to prototype and flight demonstrate hybrid FSO/RF air-to-air-to-ground links that combine the best attributes of both technologies and simulate hybrid network performance. The ORCLE technology is planned for transition to the Air Force in FY 2007.

(U) Program Plans:
- Developed a networking schema for quality of service using RF for latency sensitive assured delivery and FSO for bulk high bandwidth transfers that are less latency sensitive using a dynamic & synergistic dual physical layer.
- Developed compact beam steering using a small form factor and wide field of view.
- Perform range and flight demonstrations of air-to-air-to-ground hybrid FSO/RF links with high availability and gigabit data flows.
- Investigate the optical channel obscuration mitigation using ultra short pulse lasers and partially coherent beams.
- Execute common/combined FSO/RF apertures that enable transition to operational platforms as replacements rather than addition to current systems while maintaining or improving current capabilities.

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	FY 2005	FY 2006	FY 2007
Policy Based Network Management (PBNM)	1.687	4.599	0.000

(U) Drawing upon lessons learned from the Airborne Communications Node/Adaptive Joint C^4ISR Node (ACN/AJCN) program and previous DARPA programs in mobile ad-hoc networking, the Policy Based Network Management (PBNM) program seeks to enable reliable and understandable control of non-homogeneous ad-hoc networks and other communications systems that must interact to support the commander's mission objectives. This effort seeks to create a system control methodology that will allow intuitive control over complex communications systems while still preserving the flexibility of the emerging ad-hoc networks. In addition to creating a method for an operator to understand the state of the network, PBNM will allow the network to implement the commander's intent for the operation by dynamically changing function and allocation throughout the duration of a mission. PBNM will control traffic at the application level by making the system aware of what is currently possible, what is currently allowed, and how communications are expected to change over the duration of a mission.

(U) Program Plans:

– Demonstrate, using wireless networked communications, the ability to control information traffic to satisfy commander's intent and mission needs.

	FY 2005	FY 2006	FY 2007
Disruption Tolerant Networking (DTN)	7.042	6.633	8.065

(U) Drawing upon technical challenges identified in specific programs, such as the Airborne Communications Node/Adaptive Joint Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C^4ISR) Node (ACN/AJCN) and other non-ground based Mobile Ad-Hoc Network (MANET) programs, the Disruption Tolerant Networking (DTN) program will develop network protocols and interfaces to existing delivery mechanisms ("convergence layers") that provide high reliability information delivery using communications media that are not available at all times, such as low earth satellites, UAV over-flights, orbital mechanics, etc. The program will develop a single model for bundling information and ensuring its delivery, even through a series of episodic communications links, from generator to user. To maximize the applicability and commercial viability of these protocols, and develop the basic software in an open source mode, the military, commercial and

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Internet communities will be engaged. These protocols will be implemented in a typical military system to verify both the performance of the protocol and to validate the utility. These protocols are also applicable to NASA applications, such as deep space communications. The Disruptive Tolerant Networking technology is planned for transition to the Army in FY 2009.

(U) Program Plans:
- Demonstrate that information organized into bundles can be delivered across intermittent networks.
- Commence research to show “fuzzy scheduling” can make network routing decisions in the presence of uncertainty about available or optimal paths.
- Investigate policy cognitive operation by moving intelligence into networks to make the best choices on delivery.
- Enable networks to deliver traffic without the end-to-end address and routing information using deferred, hierarchical address binding techniques.
- Develop mechanisms to allow code-base-independent environmentally-aware selection of routing algorithms.
- Demonstrate trusted delivery of bundles across networks in which access to a PKI is not reliable.

	FY 2005	FY 2006	FY 2007
Network Centric Operations/Battle Command	7.452	9.054	11.584

(U) The DoD is transforming to a more network centric focus for military operations. Network centricity, among other benefits, facilitates the sharing of situation information and access to resources. Shared situation awareness enables collaboration and self synchronization at all operational levels thereby greatly increasing mission effectiveness. Military campaigns in the future will not necessarily be focused solely on major military operations. These campaigns will involve attempts at conflict avoidance, and if this fails, possibly major combat operations with periods of various security, stability, reconstruction, transformation and transition operations. Future campaigns will be characterized by an increased demand for the commander to employ the most appropriate actions (diplomatic, information operations, military, economic, etc.) against the adversary’s various political, military (air, land and sea; regular or irregular), economic, social, information distribution, infrastructure, etc. systems. Commanders in the future will use network centricity to access a larger base of knowledge sources and a greater range of resources and actions. Concurrently, the commander will be challenged to exploit these capabilities to achieve a mixture of appropriate effects.

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(U) Until recently, the primary technological emphasis for network centric operations has been on improving command, control, communications and computing, intelligence, surveillance and reconnaissance (C^4ISR) systems to enable better sensor-decider-shooter linkages. While appropriate, there must also be more emphasis on technologies to assist commanders in: 1) understanding the complex operational environment, developing and managing effects-based campaigns that employ all options available to the commander, and synchronizing combat operations, security, stability, reconstruction, transformation and transition operations over the entire time of the campaign; 2) enabling tactical units to self synchronize to exploit targets of opportunity by applying effects using any weapon or effect generator, any sensor system, from any of the services, from the U.S. or its allies, on land, air, maritime or space platforms to immediately create effects against targets on land, in the air or on the sea; and 3) communicating seamlessly across mobile ad hoc networks, data links, fixed and transportable networks as well as commercial systems.

(U) Initial technologies developed in the program are planned to transition to the Army Network Enabled Battle Command program and to the U.S. Joint Forces Command as an initial capability in FY 2006, with more comprehensive capabilities transitioning in FY 2007 and FY 2008.

(U) Program Plans:

- Develop and demonstrate technologies for integrating modeling and visualization techniques into action/effects exploration and campaign planning with an emphasis on modeling an adversarial coalition's various political, social, economic, information dissemination, service infrastructure, etc. systems as well as its military or insurgent capabilities.
- Develop and demonstrate technologies to support humans in authoring courses of action, development and campaign planning; decompose objectives, to effects, to nodes, to actions; capture and model interdependencies between assumptions, activities and intended objectives, and between intended and unintended effects; and assist the human in synchronizing objectives and activities.
- Develop and demonstrate technologies to enable tactical entities to autonomously, dynamically, self synchronize activities in accordance with the commanders guidance in a decentralized, distributed manner and enable commanders to synchronize guidance to ensure harmonious interaction of tactical entities.
- Develop and demonstrate a single, common C^4ISR system architecture and a common technology building block for seamlessly integrating the strategic, operational and tactical levels of warfare.
- Develop interface systems for seamlessly integrating data from self-forming, mobile, ad hoc, tactical networks into high data rate internet-type networks like the Global Information Grid (GIG).

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	FY 2005	FY 2006	FY 2007
Advanced Antenna Concepts	4.152	5.711	6.075

(U) The Adaptive Amplification effort will enable small wireless devices, antennas, and associated components to provide similar effectiveness to larger ones. Current antenna technology limits the ability to miniaturize the physical size of the antenna, resulting in a requirement for large platforms or physical deployments for special operations. Similarly, limited antenna bandwidth limits the ability to fully exploit software-based radios, such as Joint Tactical Radio System (JTRS), since the antennas they utilize are limited in bandwidth. Application of advanced technology offers the ability to fabricate devices that can effectively couple to very non-resonant antennas. The basic technology has been developed for application to small-sized radios with wide bands of operation.

(U) The Ultra-Fast Radar effort will entail the design, construction, and demonstration of an X-band noise correlating radar with a retro-directive antenna. This effort will research and develop a new type of radar sensor based on the correlations of the Gaussian noise received by an antenna array from a small object located in the far field of the antennas and the retro-directive re-radiation of the correlated noise. The combining and tailoring of noise correlating interferometry and retro-directive antenna arrays into retro-directive noise-correlating (RNC) radar will allow the radar to operate in omni-directional search mode. The result of this project will be a new type of search-mode radar having promising performance in terms of short acquisition time and low probability-of-intercept. The Ultra Fast Radar technology is planned for transition to the Army in FY 2007.

(U) Program Plans:

- Adaptive Amplification
  - Identified promising technologies.

- Ultra-Fast Radar
  - Develop an X-band noise correlating radar with a retro-directive antenna to show an approximately 5-times reduction in acquisition time compared to traditional electronically-steered search-mode radar, and an even greater reduction in comparison to mechanically scanned radar.

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-- Design and demonstrate ultra-fast radar using retro-directive antenna arrays that will show a significant reduction in probability-of-intercept compared to traditional search radars based on coherent transmitters.
-- Determine if the concept offers significantly reduced cost and greater simplicity to radar development and antenna designs than current systems.

	FY 2005	FY 2006	FY 2007
Fiber-Optical Network for Aerospace Platforms (formerly Navy Photonics Program)	3.758	4.000	4.750

(U) The Fiber-Optical Network for Aerospace Platforms program will facilitate building or upgrading military aircraft and other aerospace platforms with a future-proof fiber-optical networking infrastructure with many capabilities that are well beyond those of currently used copper-based technology. Originally, the program focused on specific technologies for application on the Navy's EA-6B Prowler aircraft, however, the program has now been restructured to focus on technologies that will provide advanced capabilities to a multitude of military aircraft and aerospace platforms. These new capabilities include: scalability in bandwidth and number of connected devices; immunity to electromagnetic interference (EMI) and cable cross-talk; reduced cable and overall system weight and volume; increased reliability without an associated weight or volume penalty; ease of integration and future upgradeability; and the ability to carry mixed analog and digital signal formats. This will be accomplished by taking full advantage of fiber-optical wavelength-division-multiplexing (WDM) technology and leveraging optoelectronic and photonic integration techniques developed in DARPA photonics components program. To reduce size, weight and power requirements and to increase the reliability and the flexibility of interconnecting arbitrarily placed client devices with various signal formats, use will be made of passive, transparent, wavelength-routing technology at the core of the network, and tunable optical transmitters and receivers (transceivers) to inter-connect the client devices at the edge of the network. The technologies developed under this program are planned for transition to the Services in FY 2010.

(U) Program Plans:
- Compile an extended superset of the requirements for a network to be deployed in various target aerospace platforms.
- Create a suitable architecture for a mostly passive, wavelength-division-multiplexing (WDM) fiber-optical network with high connectivity for increased reliability.
- Develop a wavelength plan for interconnecting arbitrarily placed client devices using tunable optical transceivers.

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- Develop a protocol for rapid restoration from multiple failures through protection switching or by re-tuning the optical transceivers.
- Conduct an analysis to estimate the resulting network reliability and survivability under various failure scenarios.
- Demonstrate the ability to interconnect client devices with a wide range of analog and digital signal formats.
- Demonstrate the ability to integrate the appropriate combinations of optical devices and components to reduce weight and volume.
- Build and flight-test a network test bed that is representative of a network suitable for one or more target aerospace platforms.

	FY 2005	FY 2006	FY 2007
Advanced HF Communications	0.000	1.842	3.300

(U) The goal of the Advanced HF Communications program is to provide always-available, high-rate communications at long ranges for Special Operations Force (SOF) teams using miniaturized equipment. Currently SOF teams rely on satellite communications (Satcom) for long range connectivity. However, Satcom requires line of site access, and channel availability. The Advanced HF Communications will develop antenna and radio technology to provide high-rate communications at long ranges using ground wave and near vertical incidence skywave (NVIS) propagation. A fundamental challenge is reducing the size, weight and power (SWaP) requirements for SOF applicability. Novel miniature HF antenna technologies and channel adaptive radio technologies will be developed and demonstrated in man portable form factors. The technologies developed under this program are planned for transition to Special Forces in FY 2009.

(U) Program Plans:

- Investigate novel antenna designs for miniature form factor and high efficiency.
- Perform propagation experiments to determine atmospheric effects on communications using both ground wave and NVIS electromagnetic propagation modalities.
- Develop improved statistical models of atmospheric effects on communications to implement effective equalization techniques using state of the art digital signal processing components and algorithms.
- Develop a dual mode transceiver prototype in a package that validates the size, weight and power requirements of the SOF user.
- Perform a field demonstration on a prototype transceiver in various environments to validate the concept.

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	FY 2005	FY 2006	FY 2007
Communications to the Tactical Edge	0.000	4.375	7.843

(U) The future DoD communications architecture will provide a multi-tiered capability consisting of: a worldwide, broadband Global Information Grid (GIG); transportable networks like the Army Warfighter Information Network-Tactical (WIN-T); and totally wireless mobile ad hoc tactical networks formed using the next generation Joint Tactical Radio System (JTRS) terminals. This project will provide technology to make networks "user-aware" and oriented toward delivering tailored services to each user by dynamically balancing communications supply and demand. An Information Flow Control Network will be created to act as a dynamic overlay to existing communications networks while simultaneously serving as an underlay to existing service oriented architectures and other middleware. Rather than provide "best effort" with no guarantees, the Information Flow Control Network will provide "best service" with guarantees. The Communications to the Tactical Edge program will transition to the Army in FY 2009.

(U) Program Plans:

- Develop technology to implement a user-transparent service that dynamically monitors the communications supply available and the communications demand desired at each user (or end system) and is aware of the military missions being executed by each user.
- Develop middleware technology to dynamically negotiate and control demands to meet supply by means such as context-preserving content reduction.
- Develop middleware technology to dynamically negotiate and control access to communications services (supply) by methods such as dynamically assigned use of the military multi-level priority and precedence system or other dynamic quality of service parameters.
- Perform trial demonstrations using simulation and emulation over existing backbone networks.

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	FY 2005	FY 2006	FY 2007
Self-Forming Networks	0.000	4.606	1.648

(U) The Self-Forming Networks program seeks to develop networks that use addresses that are distributed topographically (e.g., geographically or by organizational unit). Current network routing methodologies use IP address numbers that are distributed in no defined pattern or methodology. As a result, current routing systems spend large amounts of time and computing power updating and maintaining tables that 'point' to where different IP addresses are located geographically. The Self-forming Networks will reduce the load on routers as well as greatly simplify router configuration. These networks will be a paradigm shift in that numbered IP addresses will no longer exist, and changes to the Domain Naming Server (DNS) system will allow for services to mobile users to be incorporated. This program is planned for transition to the Services in FY 2009.

(U) Program Plans:

- Develop machine naming schema for data packets that are geographically based and that allow for fine grained control of precedence and improved quality of service capabilities.
- Develop tactical router replacements that work with existing computers/routers and require no new configuration and enable self-forming networks that will result in at least an order-of-magnitude reduction in training, configuration, and installation time.
- Develop changes to DNS functions to accommodate the forwarding services to mobile users.

	FY 2005	FY 2006	FY 2007
Scalable MMW Architectures for Reconfigurable Transceivers (SMART)	0.000	5.370	7.499

(U) This program, formerly Ideal RF Link, seeks to exploit recent advances in analog transmit and receive technology with progress in ultra-high speed logic to simultaneously reduce the transceiver phase noise and reduce analog device non-linearities with digital correction techniques. In particular, the current performance of Silicon Germanium and Indium Phosphide bipolar device technology is now fast enough, with cut-off frequencies of > 350 GHz, that error correction technique such as predistortion and feed forward correction can be considered for application to

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RF components. The effort will develop new circuit topologies and algorithms along with cross technology integration schemes. This combination will increase the maximum signal data rate (increase the bits/sec/Hz) for DoD RF links.

(U) Program Plans:
- Study fundamental limits to RF communication links and perform system study.
- Define critical technical challenges to increasing link margin by improving component linearity.
- Establish program metrics for optimum RF link demonstration.
- Initiate component development and heterogeneous integration demonstrations.

	FY 2005	FY 2006	FY 2007
DARPA Interference Multiple Access (DIMA) Communications (formerly R^3I Network)	0.000	5.080	7.458

(U) The DARPA Interference Multiple Access (DIMA) Communications program will develop a networked radio system that supports voice and data. The goal of this program is a network that is dynamically controllable using techniques such as reconfiguration, optimum resource allocations based on mission priorities, and dynamic policies, as opposed to relatively passive reactions to changes by the commercial infrastructure. This program will initially develop direct sequence spread spectrum (DSSS) communications technologies as a building block to enable robust, mobile, tactical wireless networks, which are the foundation for network centric warfare concepts. The fundamental technical challenges are scalability, covertness, robustness and platform size, weight and power requirements. The DIMA Communications program will develop and demonstrate a DSSS system based on multi-user detection concepts that can operate in an infrastructureless (ad-hoc networked) environment. The technologies developed under this program are planned for transition to the Army and SOCOM in FY 2008.

(U) Program Plans:
- Demonstrate feasibility of concept in a wireless test bed.
- Develop optimized waveform, multi-user detection processing and channel parameter estimation algorithms.
- Demonstrate system performance through a combination of simulation and hardware prototype field demonstrations.

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	FY 2005	FY 2006	FY 2007
Terabit Optical Ethernet	0.000	0.000	2.100

(U) The Terabit Optical Ethernet (TOE) Program will develop and demonstrate tera-bit per second optical routing using a distributed routing concept that will enable a three order of magnitude reduction in size and weight requirements over current routing technology. This technology routes each transmitted packet via a wavelength based on the destination node in a ring architecture. A major technical challenge is obtaining the ability to quickly and precisely tune the laser source. This program will develop Terabit Optical Ethernet Network Interface Cards that will demonstrate the throughput, scaling and weight reduction potential of this technology. Strong interest has been expressed by the user community for the dissemination in real time of the large volume, high value metadata that the next generation of sensors will produce, while at the same time providing on demand access to stored information. This will enable breakthroughs in the rapid exploitation and analysis of critical high-bandwidth sensor data needed to support DoD operations. Technologies developed under this program will transition to Service Applications in FY 2008.

(U) Program Plans:
- Develop the system design for the TOE network interface card.
- Develop a hardware prototype and demonstrate the capabilities.

	FY 2005	FY 2006	FY 2007
Multiple-Input / Multiple-Output (MIMO) Satcom	0.000	0.000	2.950

(U) The MIMO Satcom program will develop a proof of concept system that will enable multiple users access to 100 kilobits per second (kbps) satcom channels using the existing C-band satellite architecture. This new capability becomes possible, in part, by moving away from the existing paradigm regarding usage of these satellites. This new MIMO Satcom paradigm envisions satellites as merely a node or relay for a single user. In communications terminology, the satellite is part of a single-input / single-output (SISO) channel. Instead, this program will consider the multiple satellites simultaneously. Using this approach, a multitude of co-channel users send signals that illuminate a multitude of satellites. Powerful processing algorithms then isolate the individual communication links. Using the constellation in this manner provides signal gain and interference rejection.

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(U) The most important advantage for military missions is the ability to use the existing C-band uplink infrastructure with antenna aperture areas several orders of magnitude smaller than are currently needed. The large size of current C-band ground station antennas is driven by the need to limit adjacent satellite interference rather than the need for additional link margin. Operation with drastically reduced apertures is possible if the requirement to avoid illuminating an adjacent satellite is removed. By relaxing beam size requirements the ground terminal footprint can be reduced. Other satellite constellations with reduced coverage offer greater power and, hence, more capacity.

(U) The increased complexity of the MIMO Satcom communication link demands dynamic and adaptive network protocols to ensure optimal performance is achieved. The technologies developed under this program will transition to the Services' expeditionary forces in FY 2008.

(U) Program Plans:
- Develop the system design requirements.
- Develop the system components.
- Integrate the components and demonstrate the communications capability.
- Demonstrate the fundamental capability enhancement using processed data.

	FY 2005	FY 2006	FY 2007
Wireless Network after Next (WNaN)	0.000	0.000	3.700

(U) The Wireless Network after Next (WNaN) program goal is to develop and demonstrate technologies and system concepts enabling densely deployed networks in which distributed and adaptive network operations compensate for limitations of the physical layer of the low-cost wireless nodes that comprise these networks. WNaN networks will manage node configurations and the topology of the network to reduce the demands on the physical and link layers of the nodes. The technology created by the WNaN effort will provide reliable and highly-available battlefield communications at low system cost.

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(U) The WNaN program will develop a prototype handheld wireless node that can be used to form high-density ad hoc networks and gateways to the Global Information Grid. This program will develop robust networking architecture(s) that will exploit high-density node configurations from related DARPA programs. This program will culminate in a large-scale network demonstration using inexpensive multi-channel nodes. WNaN technology is planned for transition to the Army in 2010.

(U) Program Plans:
- Design and build wireless nodes incorporating 4 channel inexpensive RF circuits.
- Demonstrate a communication system where the network layer can mitigate shortfalls in the physical layer.
- Demonstrate a 500 to 1000 node integrated WNaN system.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	60.897	125.384	48.975	51.480	71.092	76.890	77.097
Rapid Strike Force Technology LNW-01	3.334	34.584	38.925	51.480	71.092	76.890	77.097
Future Combat Systems LNW-03	57.563	90.800	10.050	0.000	0.000	0.000	0.000

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

(U) his 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.

(U) The emerging U.S. vision of future land warfare places strong emphasis on technology supporting early entry of light, efficient land forces, particularly in urban areas where both combatants and civilians are present. This project is developing technologies that serve as force multipliers, enabling safe and effective operations in hostile environments. Revival of this project stems from the need to support the development of effective and adaptive weaponry, both lethal and non-lethal, for a variety of target suppression effects. Other technologies to be explored will include tele-operated systems, novel targeting and firing techniques, and advanced situational awareness and response systems.

(U) The U.S Army's Future Combat Systems (FCS) is envisioned to be a System of Systems (SoS), which will provide capabilities that strike an optimum balance between critical performance factors (e.g., operational and tactical mobility, lethality, survivability, and sustainability) and strategic responsiveness. The FCS program embraces an evolutionary acquisition, spiral development process. The first FCS SoS Unit of Action (UA), equipped with the eighteen (18) FCS Systems, plus the Network, will be initially fielded in 2014. The program allows for continuous capability upgrades through the introduction of new, enabling technologies throughout the development phase. This Joint DARPA/Army activity supports the FCS spiral process through the development of critical technology improvements for FCS platform variants and the Network. The resulting network-centric SoS will continue to provide the Unit of Action overwhelming lethality, strategic deployability, self-sustainment, and high survivability over other conventional ground forces.

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(U) Program Change Summary: *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	62.546	139.100	66.900
Current President's Budget	60.897	125.384	48.975
Total Adjustments	-1.649	-13.716	-17.925
Congressional program reductions	-0.048	-13.716	
Congressional increases	0.000		
Reprogrammings	0.000		
SBIR/STTR transfer	-1.601		

(U) Change Summary Explanation:

FY 2005	Decrease reflects the DOE transfer directed for P.L. 108-447 and the SBIR/STTR transfer.
FY 2006	Decrease reflects congressional cuts to DPX-5 and C-130 STOL Demo, undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Decrease reflects repricing of efforts in Project LNW-01, Rapid Strike Force Technology, and reductions to Future Combat Systems technologies reflecting transitions of technologies and managerial control to the U.S. Army.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Rapid Strike Force Technology LNW-01	3.334	34.584	38.925	51.480	71.092	76.890	77.097

(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, particularly in urban areas where both combatants and civilians are present. This project is developing technologies that serve as force multipliers, enabling safe and effective operations in hostile environments. Revival of this project stems from the need to support the development of effective and adaptive weaponry, both lethal and non-lethal, for a variety of target suppression effects. Other technologies to be explored will include tele-operated systems, novel targeting and firing techniques, and advanced situational awareness and response systems.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Boomerang	3.334	0.000	0.000

(U) The goal of the Boomerang program was to rapidly develop and demonstrate affordable and reliable acoustic gun shot detection and localization techniques. The program focused on enhancing the safety of vehicle convoys and increasing situational awareness. Based on previous acoustic shot detection work, Boomerang developed system hardware design and packaging, vehicle integration concepts, user interfaces and signal processing algorithms and software for prototype systems, as well as continued refinement of algorithms, hardware and software to improve system performance and accuracy. Acoustic sensors, mounted in an array at the top of a mast, are used to detect both supersonic shock and sound waves from muzzle blast and then identify the location of the shooter. Users receive simultaneous visual and auditory information about the point of fire from an LED display and speaker. Boomerang systems were tested by warfighters serving in Operation Iraqi Freedom (OIF). The systems were designed for ease of use, installation and field upgradeability. Shot data collected from a series of CONUS firing tests and from systems deployed to OIF demonstrated that Boomerang provides troops the ability to detect and locate supersonic shots for both moving platforms and stationary applications, thus providing increased force protection capabilities. Comments from deployed troops were collected and analyzed. As a result, an improved version of the Boomerang system with significantly smaller acoustic arrays (designed to reduce visual

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footprint) was developed with enhanced crew display, increased detection range, ability to provide shooter's elevation, and improved electro-magnetic interference thresholds so as not to interfere with tactical combat radios used by Marine and Army units.

(U) Program Plans:
- Improved performance based on data from deployed systems, user feedback and evolving concepts of operations.
- Conducted extensive testing on the enhanced system to validate improved system performance, reliability, and robustness.
- Fabricated and delivered updated systems to deployed warfighters for field testing.

	FY 2005	FY 2006	FY 2007
Multi-Modal Missile (M3)	0.000	9.000	9.500

(U) The Multi Modal Missile (M3) program will explore the development of an integrated, man-portable weapon system capable of performing surface-to-surface, anti-armor, and surface-to-air anti-aircraft missions with an emphasis on extreme precision. The program will focus on delivering precision targeting accuracy to 1) enable light-weight munitions and thus deeper magazine and/or longer engagement ranges, 2) tailor categories of kill through subsystem targeting, and 3) provide lethal effects against targets otherwise beyond the reach of man-portable weapons. The objective M3 capability will integrate a variety of existing weapons-systems functions and provide the dismounted soldier with a compact system to engage vehicles, rotorcraft, and close air support aircraft. The effort will also explore additional mission concepts to include anti-personnel and breaching applications, beyond-line-of-sight functionality, air-to-ground capability, and ground vehicle mounting options. Critical characteristics of this weapon system concept include light weight, simple operation, and affordability. Technologies under consideration will include advanced imaging seekers and/or operator terminal guidance; low-cost, high-performance, solid-rocket engines; sensor-based fusing; and novel warhead concepts to support a wide range of engagement geometries with desired lethality effects against a range of targets.

(U) Program Plans:
- Perform initial system design analyses and trade off studies.
- Initiate critical technology, maturation efforts for seeker, propulsion, guidance and warhead.
- Develop, analyze and assess initial multi-modal missile system preliminary designs.

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	FY 2005	FY 2006	FY 2007
Non-Lethal Alternatives for Urban Operations	0.000	8.000	4.500

(U) The Non-Lethal Alternatives for Urban Operations effort will explore system concepts and enabling technologies for non-lethal weapons in challenging urban and semi-urban environments. This effort will assess effects, targeting systems, delivery systems, and countermeasures, and will develop integrated less-lethal system options for application to urban warfighting. Effects to be investigated will include less-lethal projectiles, malodorants, entanglers, and marking agents. The effort will consider direct and indirect fire systems to counter personnel and to provide area effects against vehicles, crowds and groups of combatants. Operating scenarios to be explored will include force protection for fixed sites, force protection for mobile forces, situational control (including traction control), individual soldier weapons, border protection, and protection of extended infrastructure. The effort will pay particular attention to technologies that support application on autonomous and teleoperated unmanned ground robotic vehicles in urban environments at a sustained operational tempo. Transition organizations will be identified as efforts and systems are developed.

(U) Program Plans:

- Perform initial concept development and effects assessment.
- Develop initial urban less-than-lethal system design.
- Begin focused less-than-lethal technology maturation efforts to address and reduce system risk.
- Develop and demonstrate technologies in an end-to-end system.

	FY 2005	FY 2006	FY 2007
Tactical Urban Operations (TURBO) program	0.000	8.182	3.425

(U) One of the key reasons for the overwhelming effectiveness of U.S. forces in large scale warfare is the ability to perform reconnaissance and strike with impunity from the air, in coordination with ground forces. The Tactical Urban Operations (TURBO) program will extend this capability to low-level ground forces in urban (and other) settings by providing close integration of dismounts with information from low-level

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airborne assets, such as the Micro Air Vehicle (MAV) or the Organic Air Vehicle (OAV), local intelligence sources, and responsive and improved fires / effects capable of acting on this information. Technologies to be explored include: aggregation of information from multiple MAVs and OAVs with that from other sources into an easy-to-use interface, improved techniques for detecting dismounted targets and distinguishing friend from foe, and improved methods for displaying information to dismounts and allowing them to direct operations without impeding their mission. These systems will be developed within the framework of both legacy forces and expected future forces. The result will be to provide dismounted soldiers with the ability to obtain greatly improved reconnaissance and "close air support" in urban settings. The program will be a multi-phase program with frequent user reviews to ensure that the resulting products are meaningful and affordable. The program will culminate with a series of prototype demonstrations of the capabilities in a surrogate urban combat environment.

(U) Program Plans:

- Define system architecture and constraints in conjunction with user group.
- Develop and demonstrate technologies and evaluate to determine system effectiveness.
- Initiate second phase to improve selected technologies and integrate them into the overall TURBO system.
- Perform live fire demonstration of soldier-level ground / air team and remote precision munitions to demonstrate improved situation awareness and responsive fly-in-the-foxhole and fly-in-the-window accuracies.

	FY 2005	FY 2006	FY 2007
PEO-Soldier/Exoskeleton Transition	0.000	9.402	6.000

(U) The PEO-Soldier Exoskeleton Transition Program will employ novel mechanisms, information systems, and power management hardware and software to ultimately produce a wearable machine that will serve as an intuitively operated load carriage system for individuals. The goal of the program is to enable an individual soldier to lift and carry 150 pounds while feeling only a small part of the load, work for long periods of time, and to travel in difficult conditions. This ability for a single soldier to carry heavy loads could be leveraged in applications ranging from moving boxes of ammunition or supplies to enabling the carriage of significantly greater body armor than is presently possible. The Army envisions the Personal Combat Vehicle (PCV) to be a highly armored anthropomorphic vehicle for the individual soldier that can move through

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rough and urban terrain without difficultly while providing the individual soldier with an unprecedented amount of ballistic protection. This program has transitioned from PE 0602715E, MBT-01, where the underlying smart materials and mechanism development was funded.

(U) Program Plans:
- Develop the enabling components and improve the overall system performance of the exoskeleton device against threshold requirements developed in an MOA with the Army (May 2005).
- Transition exoskeleton technology to the Army with cost share in FY 2006 and FY 2007 with complete transition by FY 2008.

	FY 2005	FY 2006	FY 2007
Hyper-awareness Urban Force Multiplier (HYFORM)	0.000	0.000	6.000

(U) The HYFORM program, an outgrowth of the Tactical Urban Operations (TURBO) program also budgeted in this project, will develop a lightweight and unobtrusive audio and visual interface with robust high-bandwidth communications allowing the soldier not only instant access to real-time ubiquitous sensor data (imaging, night vision, satellite/UAV data, etc.), but also act as the interface to an entire tactical intelligence center consisting of both automated and human-in-the-loop analysis. Techniques such as dynamic information encoding, multi layer waveforms and predictive routing that adapt across multiple layers will be developed. Thus a single soldier can have virtually unlimited real-time reach-back support while not incurring the enormous force protection and logistics cost. Key enabling technologies may include miniature heads-up-displays (HUDs), compact multimode communication receivers (e.g., RF, EO/IR, etc., to maintain link in urban canyon), retinal scanners, multidimensional surround sound, and voice activated computer interfaces for the embedded soldier, as well as knowledge aided and adaptive computing at the support center. HYFORM should have access to non-line-of-sight radar to see behind buildings and maintain track of mobile targets. This non-line-of-sight capability will develop new radar and electro-optic/infrared (EO/IR) integration to track vehicles over wide urban areas. Thus the output of the HYFORM program will be an extremely compact, lightweight acousto-optic interface with a robust communication link back to the computer/command center.

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(U) Program Plans:

- Architecture and sensor conceptual design for multi-sensor/multi-point operation.Communication and sensor sizing to determine operational requirements.
- Analysis to determine achievable qualitative performance.
- Develop techniques such as dynamic information encoding, multi-layer waveforms and predictive routing that reliably penetrate the urban infrastructure and cope with rapidly changing propagation.
- Develop candidate conceptual designs meeting objective system performance.
- Brassboard demo of basic penetration performance.
- Experimental field trials.
- Full prototype development and demonstration.

	FY 2005	FY 2006	FY 2007
Standoff Explosives and Concealed Weapons Detection	0.000	0.000	3.500

(U) The Standoff Explosives and Concealed Weapons Detection program will develop a standoff system for the detection of improvised explosive devices (IEDs), suicide bombs and vehicle bombs that have become weapons of havoc and destruction in current urban operations; as well as a low cost concealed weapons detection system. This program will explore various phenomenologies that may permit explosive detections. The first approach will examine chemical approaches such as spectrometry using IR photothermal signature of the explosive compounds, or standoff detection using molecular tags that change physical, electronic, or optical properties upon exposure to emitted vapors. These tags provide specific molecular information on the signature chemicals, thus enhancing specificity in the cluttered environment. They could be deployed as dust or chaff that can be dispersed in the air or sprayed on suspect vehicles, or into larger sensor structures that could be used to integrate the concentration of vapor over time. Yet another approach is the development of integrating, reactive collectors that can be broadly distributed and sensed remotely. Imaging based approaches will be developed that could allow stand-off detection of weapons or explosives on individuals. Integrated silicon-based antenna array receiver devices could produce whole radar arrays on a single die. Advanced front-end lens/reflector subsystems composed of lightweight, low cost materials must be developed in conjunction with highly sensitive receiver subsystems to extend the standoff range. High-performance, real-time image processing algorithms must be executed in real-time and would require the

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development of a lightweight, low-power processor. This combined standoff concealed weapons detection system could result in a significant reduction in military and civilian casualties.

(U) Program Plans:
- Conceptual verification to determine qualitative performance achievable of chemical-based approaches and stand-off imaging.
- Develop candidate conceptual designs meeting objective system performance.
- Laboratory prototype demonstration.
- Brassboard demo of basic penetration performance.
- Experimental field trials.
- Transition to operational forces.

	FY 2005	FY 2006	FY 2007
Urban Obscurants	0.000	0.000	3.000

(U) The Urban Obscurants program will develop a system, inherently immune from countermeasure that obscures U.S. operations while maintaining visibility of the enemy. This system would potentially provide a new operational capability for conducting building raids, clearing facilities, and perhaps even masking convoy movement in the urban theatre.

(U) Key technical challenges are associated with developing a system intrinsically immune from countermeasures. Initial studies have shown optical analogs of secure digital communication hold great promise for providing a "coded" obscurant system. The optical properties of obscurant can be tailored such that they develop transparency at narrow, tunable wavelengths. This narrow band optical bleaching phenomena could be realized through optical threshold sensitive switching materials akin to some developed for laser protection goggles. The U.S. Army PM-Obscuration and Decontamination Systems will be the likely transition partner. This program is an outgrowth of the Non-Lethal Alternatives for Urban Operations program also budgeted in this project.

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(U) Program Plans:
- Develop and test particulate materials that are spectrally agile.
- Determine and enhance human safety of materials.
- Determine particulate loading that obscures vision of enemy while maintaining vision of allies.
- Develop and test particle dispersion methods.
- Integrate particulate materials with dispersion devices to produce urban obscurant system.
- Test integrated system and transition to operational forces.

	FY 2005	FY 2006	FY 2007
Urban Counter Mortars	0.000	0.000	3.000

(U) The Urban Counter-Mortars (UCM) program will provide persistent surveillance and tracking of mortar launches. With precision sensor positional knowledge, the UCM will backtrack the mortar to within 0.5 meters of the insurgent location within seconds of the initial launch – enabling an automated counter-fire solution that will impact the insurgent location before they disappear while limiting collateral damage.

(U) To achieve these performance parameters, the UCM program will develop the precision multisensor network metrology necessary for extremely small angular resolution. The distributed sensor system requires precision knowledge of each sensor location within the urban coordinate system, sub-nanosecond shared system timing, extremely-fast Mid Wave Infrared (MWIR) and Long Range Infrared (LWIR) detectors, and the tracking algorithms to enable 0.5 meters Circular Error Probability (CEP) geolocation within ten seconds of the mortar launch. Competing system concepts include stereo-imaging and single-sensor with a LADAR. The UCM program will develop the competing systems in the context of ten year operational lifetimes, affordability, and applicability to providing guidance corrections to the counter-fire response. The final system design will transition to the U.S. Army for integration into the perimeter defense systems.

(U) Program Plans:
- Develop objective system concepts demonstrating persistence, accuracy, and speed.
- Develop high-fidelity physics-based urban background models; validate with data.

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- Develop precision individual and network sensor positional knowledge.
- Develop advanced knowledge-aided signal processing algorithms.
- Demonstrate 0.5 meters CEP calculations less than 10 sec post-launch.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Future Combat Systems LNW-03	57.563	90.800	10.050	0.000	0.000	0.000	0.000

(U) Mission Description:

(U) The Army's Future Combat Systems (FCS) is envisioned to be a System of Systems (SoS), which will provide capabilities that strike an optimum balance between critical performance factors (e.g., operational and tactical mobility, lethality, survivability, and sustainability) and strategic responsiveness. The FCS program embraces an evolutionary acquisition, spiral development process. The first FCS SoS Unit of Action (UA), equipped with the eighteen (18) FCS Systems, plus the Network, will be initially fielded in 2014. The program allows for continuous capability upgrades through the introduction of new, enabling technologies throughout the development phase. This Joint DARPA/Army activity supports the FCS spiral process through the development of critical technology improvements for FCS platform variants and the Network. The resulting network-centric SoS will continue to provide the Unit of Action overwhelming lethality, strategic deployability, self-sustainment, and high survivability over other conventional ground forces.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
FCS Supporting Technologies	57.563	90.800	10.050

(U) DARPA and the Army identified key areas where technology development is needed for potential pre-planned product improvements via the planned FCS Spirals: Class I, II and III unmanned air vehicles, robotic unmanned ground vehicles, UA and above command, control and communications, advanced radar sensor and EW systems, and advanced armament and missile systems.

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(U) The Unmanned Ground Combat Vehicle (UGCV) – Perception for Off-Road Robotics (PerceptOR) Integration (UPI) program is integrating and testing autonomous navigation algorithms with the Spinner platform to yield an unmanned ground vehicle (UGV) that operates reliably in obstacle-rich terrain. Spinners are being used as platforms to port and test methods for perception techniques to optimize autonomous performance. This integration of the best-of-class sensors and algorithms on a vehicle of Spinner's class represents a leap forward in UGV capability. Autonomous mobility is being further enhanced by the use of terrain data for path planning. The program's technologies will transfer to the FCS UGV Integrated Product Team activities to include System Development and Demonstration (SDD) efforts and potential early spirals into FCS anticipated to occur in FY 2008.

(U) The Future Combat Systems MultiCell and Dismounted Command and Control program enables experimentation with advanced command and control information technology. MultiCell emulates the functionality of an entire tactical combined arms force. The program incorporates both unmanned air and ground robotic platforms, headquarters working at the operational level, and human dismounts. MultiCell also provides commanders with recommended interface functions and workload allocations. MultiCell validates the understanding of the dynamics of complex warfighting organizations thus defining commander interface layouts, functions and displays for maximum flexibility and effectiveness. This program recommends capability enhancements supporting technology for the nomination of information sources and supports visualization of current and future operational states. MultiCell enables commanders to successfully prosecute future command and control operations with significantly reduced staff. DARPA established an MOA with the Army for this program in August 2003. The MultiCell Command and Control technology is planned for transition to the Army at the conclusion of Phase II, anticipated to be completed in FY 2006.

(U) The Maneuver C^3 program will develop robust, assured and potentially high data rate connectivity for the Future Combat Systems (FCS) elements along with a command and control architecture to reduce the number of forward deployed Command and Control (C^2) operators. The communications component will develop an integrated architecture that provides for a seamless transition from line-of-sight to non-line-of-sight communications. To enable this functionality, development of new secure waveforms, directional antennas and mobile ad hoc networks will be initiated. The C^2 component will directly leverage the Army's investment in the automation of the Battlefield Functional Areas within the Army Battle Command System (ABCS). Because of the multitude of single aspect systems that feed information in ABCS, large amounts of data are made available to the commander, thus requiring a much larger staff of operators and workstation analysts to complete the fusion function of battlefield data into information for the commander to make decisions. Future operations involving FCS technologies and operational capabilities cannot be restricted by a less responsive C^2 architecture and large support staffs.

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(U) Under the Maneuver C^3 program, the Mobile Networked Multiple-Input/Multiple-Output (MIMO) (MNM) project will pursue MIMO communication systems, which have the potential to increase data rates by 10-20 times above current systems. MIMO will use multipath to create parallel channels in the same frequency band thereby increasing spectral efficiency. This effort will demonstrate the MNM capability under dynamic urban Non-Line-of-Sight multipath channel conditions where conventional techniques are degraded. This effort will undertake advanced MIMO technology development and perform field demonstrations of mobile ad hoc networks (MANETs). This effort will culminate in the development of a wideband form-factor (Joint Tactical Radio System (JTRS) cluster 1 size PC card) system. The MNM technology is planned for transition to the Army in FY 2008.

(U) Two autonomous air vehicle programs will provide reconnaissance and surveillance, and targeting information for small unit FCS direct and indirect fire weapons. The approach is to develop autonomous vehicles for operation at two levels; a company level vertical take off and landing unmanned air vehicle (VTOL UAV) program will develop a vehicle for carrying out airborne surveillance and targeting against ground targets; and a platoon level VTOL UAV for providing small units with an organic reconnaissance and surveillance capability. The company level UAV will be developed under the OAV-II program and the platoon level UAV will be developed under the Micro Air Vehicle (MAV) program.

(U) The Organic Air Vehicle – II program will develop lift augmented ducted fan vertical flight vehicles together with their associated flight controls, collision avoidance systems, non-line-of-sight communications systems and heavy fuel engines. Once the basic flight vehicle is proven, a reconnaissance, surveillance and target acquisition (RSTA) payload, which is being developed by the Army Night Vision & Electronic Sensors Directorate, will be integrated to demonstrate mission capability. The OAV-II program will leverage several programs in DARPA and the services including advanced communications, sensor developments, the MAV ACTD, and UAV command and control programs. The dry system weight (no fuel) of the OAV II will be no greater than 112 lbs. The program will transition to the Army at the end of Phase III, which is anticipated to be in FY 2009.

(U) The primary goal of the Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration (ACTD) program is to further develop and integrate MAV technologies into militarily useful and affordable backpackable systems suitable for dismounted soldier, Marine, and Special Forces missions. The ACTD will focus on the development of lift augmented ducted fan MAVs to accomplish unique military missions, particularly the hover and stare capability in restricted environments. The objective of the MAV ACTD is to demonstrate a backpackable, affordable, easy-to-operate, and responsive reconnaissance and surveillance system. The system will provide the small unit with militarily useful real-time combat information of difficult to observe and/or distant areas or objects. The system will also be employable in a variety of war

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fighting environments (for example: in complex topologies such as mountainous terrain, urban areas, and confined spaces). The initial MAV technology development program focused on the technologies and components required to enable flight at small scales, including flight control, power and propulsion, navigation and communications. The MAV ACTD program is intended to get DARPA-developed small, Vertical Take – Off and Landing (VTOL) UAVs rapidly into the hands of the users for evaluation and evolution of the technologies; to develop tactics, techniques and procedures; and to provide a residual operational capability to active duty forces. The FCS MAV technology is planned for transition to the Army during FY 2007.

(U) The FCS LADAR Support (JIGSAW Phase III) program is developing advanced laser radar (LADAR) sensor systems and technologies for foliage penetration. Jigsaw will enable warfighters to accomplish day/night target identification and verification in the most stressing environments at short range (<1km). Environments of interest include targets hidden by foliage and camouflage, and targets in urban settings, such as alleyways. Jigsaw technologies are designed to provide warfighters with reliable combat identification based on a LADAR sensor that will deliver a visual picture of the target scene. The JIGSAW technology is planned for transition to the Army, which is anticipated to be completed by FY 2007.

(U) The Foliage Penetration (FOPEN) Reconnaissance, Surveillance, Tracking and Engagement Radar (FORESTER) initiative supports the Future Combat Systems (FCS) and the U.S. Army Objective Force. The program is developing FOPEN Ground Moving Target Indication (GMTI) radar. This radar promises persistent, long-term detection and tracking of dismounted troops and vehicles moving under foliage and in the open. The technology allows Objective Force commanders to operate with confidence in forested areas. The FORESTER radar will also be able to detect low-flying aircraft such as helicopters and ultra-lights at ranges out to 75km. FORESTER is a UHF-band FOPEN GMTI radar designed to operate on rotary wing platforms such as the A-160 unmanned helicopter. For GMTI operation, the helicopter flies into the wind to maintain near-zero ground speed. The goal is to detect dismounted troops under foliage at 30 km range under calm to low surface wind speeds. The program employs adaptive processing and innovative radar waveforms to overcome radio frequency interference and electronic countermeasures in hostile electromagnetic environments. The FORESTER technology is planned for transition to the Army at the conclusion of Phase III anticipated to be completed by FY 2008.

(U) The goal of the AACER (Affordable Adaptive Conformal ESA Radar) Program is to develop a high performance radar and communication system for Class IV unmanned helicopters such as the A-160. The Ka-band radar will provide airborne, all-weather, day-night Synthetic Aperture Radar reconnaissance, wide area Ground Moving Target Indication (GMTI) surveillance, dismount detection, and target

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acquisition and designation for precision fires. It will provide this information directly to the Unit of Action commander via an interleaved data link through the same antenna. The program will develop Electronically Scanned Array (ESA) technology in a small Ka-band antenna. The combination of platform and radar characteristics will provide for persistent surveillance including that in urban areas, with a minimum discernable velocity of 1 mph. The technologies being developed include: (1) affordable radar devices such as phase shifting elements and power amplifiers/combiners which operate at Ka band; (2) miniature receiver/exciter modules generating very broadband waveforms; (3) signal processing algorithms to support multiple functions simultaneously and detect and track dismounts. Use of existing signal and data processing hardware and software will allow an early flight demonstration of the entire system on an A-160 or surrogate aircraft. If successful, this program will provide a vastly improved intelligence and targeting capability for local commanders by providing a dedicated, rapidly taskable asset with surveillance of most of their battlespace, including areas inaccessible or obscured to larger airborne assets. DARPA negotiated an MOA with the Army for this program in August 2005, and the AACER technology is planned for transition to the Program Executive Office – Intelligence Electronic Warfare and Sensors (PEO-IEW&S) at the conclusion of Phase III in FY 2008.

(U) The electro-magnetic (EM) Mortar program will design and demonstrate EM guns (coilgun and railgun) capable of firing modified 120 mm mortar rounds with a velocity of 420 m/s. The second goal is to evaluate significant system “trade space issues” for implementation including: 1) ammunition integration and compatibility; 2) vehicle integration concerns; 3) system reliability metrics (barrel life, EM interference); 4) lethality change due to modification; and 5) system supportability metrics. Transition of developed capabilities will be accomplished through the Army FCS program, and is anticipated to occur in FY 2007.

(U) The goal of the DP-5X program was to provide a flight-ready, tactically transportable, vertical take-off and landing unmanned air vehicle (VTOL UAV) helicopter that integrated a JIGSAW sensor package and an EO/IR payload. The UAV was to be employable by a two person team and deployable in a single HMMWV. The DP-5X program was funded through FY 2005.

(U) The Future Combat Systems Studies, Analysis and Experimentation Project enables the continued Joint analysis and integration of enabling future land warfare concepts and technologies into the U.S. Army Future Combat System program. It enables the rapid analysis of opportunistic concepts and technologies, and provides support for Joint Force effectiveness modeling of DARPA enabling technologies by the TRADOC “Future’s Center.” The project has three initial focus areas: Air Assault Expeditionary Forces (AAEF), USMA Systems Engineering, and Directed Studies.

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(U) The objective of the FCS International Cooperation program is to establish and execute Science and Technology Project Agreements with the Republic of Singapore (SN) and the United Kingdom (UK) to identify new S&T initiatives. The program is in collaboration with the U.S. Army. The Singapore Project Agreement will initially support projects to investigate tactical command and control interoperability, explore the use of computer-based technology to mitigate differences between coalition partner planning processes and tools; investigate and assess the utility of various sensor packages on UAV/UGV platforms in dense jungle environments, urbanized terrain and littoral/maritime environments; and determine the applicability of quantum dot technology for developing multi-spectral optic systems. DARPA established an MOA with the Army for this program in April 2004. The agreement with the United Kingdom will initially support projects to: survey and assess international technologies applicable to the FCS program; compare and assess the coalition effects-based operations planning technologies available from the U.S. and U.K.; and, conduct an analysis of U.S./U.K. coalition interoperability. The FCS International Cooperation technology program is planned for transition to the Army by FY 2007.

(U) The Sensor Dart program will produce and demonstrate unattended ground sensors in an aerodynamic glider capable of covert delivery from a stand-off of at least 45 kilometers with a 50 meters or less circular error probability (CEP). Sensor Dart will leverage and integrate capabilities derived from prior small unmanned air vehicle demonstrator and unattended ground sensors projects. The basis for the Sensor Dart is a platform/sensor system that transitions from winged flight to earth-penetrating dart. The integration of glider and precision delivered sensor will provide a well-coupled seismic and acoustic sensing capability in support of the FCS Brigade Combat Team (BCT). The planned transition customer will be Unit of Action (UA) Product Manager Robotic and Unmanned Sensors (PM RUS) out of Fort Monmouth. Transition is scheduled to occur following program conclusion after FY 2007.

(U) The WolfPack program will further develop the initial capability for close approach electronic warfare. The overall effectiveness and efficiency of FCS will be improved by this effort through the development of an advanced, collaborative electronic warfare sensing and attack system. This will lead to improved situational awareness of the battlespace for other FCS platforms and will improve their survivability in a wide range of potential conflicts. The improved WolfPack system will be able to suppress enemy air defenses, RF communication systems, and networks either through sensing and passing back targeting information to other FCS weapon platforms for kinetic fire or by collaboratively jamming those systems and networks on its own. The WolfPack technology is planned for transition to the Army in FY 2007.

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(U) The C-130 Short Take-Off and Landing (STOL) demonstration modified an existing C-130 aircraft in order to demonstrate improvements in take-off and landing distances and maximum payload capability. This was accomplished by changing the standard 4-blade propellers to 8-blade propellers. The effort was funded with FY 2005 resources.

(U) Program Plans:

- UGCV – PerceptOR Integration (UPI)
  - Integrated perception on original Spinner.
  - Redesigned and constructed (2) Spinner vehicles.
  - Integrate Spinner payloads.
  - Commence testing of ported Learning Applied Ground Robots (LAGR) hardware on Spinner.
  - Conduct operational UPI testing of Spinners + Perception.
  - Complete testing of ported LAGR hardware on Spinner.

- MultiCell and Dismounted Command and Control
  - Develop prototype command and control interfaces for higher commanders, cell commanders and dismount commanders.
  - Conduct human-in-the-loop experiments with dismounts and higher headquarters, including joint feeds.
  - Develop supporting operational and systems architectural framework products.
  - Develop a supporting C4ISR simulation test-bed to assess the performance of the C2 prototype.

- Maneuver C^3
  - Validate organic, self-contained approaches versus approaches that “reachback” to other systems for C^2.
  - Select wireless communications network architecture(s) for implementation.
  - Demonstrate sub-system components for assured communications in a hostile environment using novel waveforms and beam steering antennas for low probability of detection and anti-jam.
  - Refine Commander’s Support Environment (CSE); expand CSE knowledge base and collective intelligence module.
  - Continue to refine and expand supporting simulation.
  - Collect and assess the insights of human-machine interface requirements for training prototypes with the assistance of Army Research Institute.

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-- Conduct experiments in support of selected command and control functions for operations with manned/unmanned systems.
-- Complete the development of an initial C^2 experimental demonstrator.
-- Continue experiments of Unit Cell C^2 incorporating limited activities of the dismounted soldier.
-- Extend C^2 architecture to handle inter-unit cell operations, and operations between unit cell and next higher level.
-- Demonstrate an integrated architecture that provides seamless transition from line-of-sight to non-line-of-sight communications via unmanned aerial vehicles and satellite communications.
-- Demonstrate new secure communication waveforms and mobile ad hoc networks using directional antennas.

– Multiple Networked Multiple-Input/Multiple Output (MIMO) (MNM)
-- Validated the MNM concept with field demonstrations of the MIMO-based Mobile Ad Hoc Network (MANET) and custom wideband RF/signal processing designs.
-- Design and demonstrate wideband antenna/RF hardware and the MIMO signal processing.
-- Design and develop a frequency agile MNM showing dynamic spectral efficiency and agility in an operational form factor for use in an urban and rural setting with applications for military and military operations other than war scenarios.

– Organic Air Vehicle - II
-- Complete Phase II of competitive contracts for system detailed design.
-- Conduct critical design review to evaluate detailed designs and downselect to the best design.
-- Complete risk reduction testing on critical vehicle subsystems.
-- Initiate Phase IIIA to build and fly a ~ 112 lb (dry weight) flight vehicle and demonstrate robust flight stability.
-- Demonstrate collision avoidance system performance.
-- Integrate RSTA payload sensors and non line of sight communications with the flight vehicle.
-- Demonstrate RSTA and target designation missions with the integrated system.

– Micro Air Vehicle
-- Demonstrate an enhanced g-MAV (gasoline engine) in military operations in urban terrain exercises and conduct experiments with troops in field trials.
-- Continue to develop small heavy fuel engines.

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- -- Provide Army unit from 25th Infantry Division, 25 MAV systems (50 air Vehicles) as a residual operational capability.
- -- Integrate a heavy fuel engine with engineering prototype vehicles.

– Jigsaw Phase III
- -- Demonstrated in a flight test campaign that Jigsaw could obtain high quality images of targets even when they were more than 95% obscured by foliage and camouflage netting.
- -- Develop a form, fit, & function Jigsaw Sensor for integration onto the DP-5X.
- -- Develop real-time on-board registration and processing capability.
- -- Perform initial flight tests and data collections to demonstrate the utility of the Jigsaw system using a UH-1.
- -- Perform flight tests and data collections using a DP-5X UAV.
- -- Advance the technologies to a Technical Readiness Level 6.

– Foliage Penetration (FOPEN) Reconnaissance, Surveillance, Tracking and Engagement Radar (FORESTER)
- -- Demonstrate detection of slowly moving ground targets in foliage by rotorcraft-mounted Ground Moving Target Indication (GMTI) radars through measurements, simulations and analyses.
- -- Design, assess, and evaluate a brassboard FORESTER hardware system.
- -- Design, assess, and evaluate a form-fit-and-function FORESTER hardware system for rotorcraft installation.
- -- Design, and fabricate a FORESTER radar and integrate it first on a Black Hawk helicopter and then on an A-160 helicopter.
- -- Conduct airborne flight-testing of the FORESTER first on a Black Hawk and then on an A-160 and demonstrate ability to do real-time detection of moving troops under foliage and in the open.

– Affordable Adaptive Conformal Electronically Steerable Array Radar (AACER)
- -- Demonstrate sub-array ESAs, 2.4 GHz waveform generator (= 3” resolution).
- -- Fabricate quadrant and full ESA array (6” x 24”) with ~ 50 W average power from 34 to 38 GHz.
- -- Integrate full array and radar system with existing processor and receiver hardware for lab testing.
- -- Develop software and demonstrate functionality in A-160 or surrogate flight platform.
- -- Train military operators and perform simulated military mission tests and evaluation.

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- EM Mortar
  - Conducted modeling and simulation to design the launcher, power supply, and projectile modifications for coupling to the launcher.
  - Designed launcher for mortar launch application and developed specifications for the power system coil and rail guns.
  - Fabricate coil and rail gun launchers.
  - Conduct laboratory testing of the launchers with capacitor-based power systems.
  - Assess large-scale manufacturing issues for capacitors and demonstrate operation in a full-size module.
  - Conduct ammunition and weapon system testing.

- DP-5X
  - Designed and fabricated air vehicles.
  - Integrated off-the-shelf gasoline engine on initial vehicle.
  - Conducted ground test of DP-5X rotor.
  - Complete integration of air vehicles with autonomous flight control.
  - Integrate and conduct flight tests of JIGSAW sensor package.

- Studies/Analysis/Experiments
  - Conduct systems engineering studies.
  - Conduct experiments with Air Assault Expeditionary Force.
  - Conduct FCS related directed studies and analysis.

- International Cooperation
  - Jointly explore and develop innovative mechanized air assault force concept of operations through enabling technologies for coalition command and control.
  - Evaluate the operational performance of DARPA Organic and Micro Air Vehicles and Unmanned Ground Vehicles in complex terrain environments, e.g. jungle and urban.
  - Evaluate the operational performance of DARPA advanced sensors and advanced sensor exploitation technologies against tactical targets in complex terrain environments, e.g. urban and jungle.

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- -- Evaluate U.S., U.K. and Singapore Command Post of the Future (CPoF) like technologies for facilitating the exchange of information and investigate concepts for command and control and explore interoperable architectures demonstrating plug and operate capabilities.
- -- Conduct interoperability wargaming.
- -- Initiate development of novel quantum dot detector technology for new design concepts for micro-sensors.
- -- Survey and assess the applicability of international technologies to the FCS program.
- -- Compare and assess the coalition effects-based operations planning technologies available from the U.S. and U.K.
- -- Analyze U.S./U.K. coalition interoperability of tactical command, control and communications systems.

– Sensor Dart
- -- Developed initial design concept that addresses separate Sensor Dart versions for a FCS Brigade Combat Team (BCT) deployment.
- -- Conducted detailed trade studies and systems analysis that will be performed to maximize system capabilities.
- -- Generated designs detailing the glider, dart, sensor, electronics, and communications subsystems.
- -- Integrate Sensor Dart subsystems for flight testing.
- -- Develop and flight test prototype glider and dart system.

– Wolfpack
- -- Demonstrated WolfPack performance in laboratory and field demonstration.
- -- Reduce form factor size of initial WolfPack capability hardware to suit multiple delivery options under the FCS architecture.
- -- Refine target set and mission roles to complement existing EW systems with unique WolfPack capabilities.
- -- Optimize initial WolfPack power generation and management systems for longer endurance.

– C-130 Short Takeoff and Landing (STOL) Demonstration Program
- -- Conducted wind tunnel tests of modified configuration.
- -- Completed necessary aero modifications for low speed stability.
- -- Installed and flight tested 8-bladed propellers.

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(U) Other Program Funding Summary Cost:

	FY 2005	FY 2006	FY 2007
PE 0603005A Army	104.800	40.000	25.000

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	118.538	134.944	174.276	178.032	170.066	172.066	173.066
Joint Warfare Systems NET-01	31.813	55.024	78.605	82.750	84.657	85.657	89.657
Maritime Systems NET-02	30.059	32.834	34.753	30.903	30.839	30.839	30.839
Classified NET-CLS	56.666	47.086	60.918	64.379	54.570	55.570	52.570

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

(U) The Network-Centric Warfare Technology program element is budgeted in the Advanced Technology Development budget activity because it addresses high payoff opportunities to develop and rapidly mature advanced technologies and systems required for today's network-centric warfare concepts. It is imperative for the future of the U.S. forces to operate flawlessly with each other, regardless of which Services and systems are involved in any particular mission. The overarching goal of this program element is to enable technologies at all levels, regardless of Service component, to operate as one system.

(U) The Joint Warfare Systems project will create enabling technologies for seamless joint operations from high-level, strategic planning to low-level, tactical operations in all environments: urban, suburban, and rural areas. The operational benefits of this project will be an enhanced ability to counter opponents' capabilities, not just facilities and equipment. This project includes efforts at the strategic/operational level that generates targeting options against opponents' centers of gravity having complex networked relationships, the operational/tactical level that manages highly automated forces with tight coupling between air and ground platforms, and the focused tactical level that develops targeting platforms that can acquire targets of opportunity cued by network-based analysis of likely enemy operations. Programs in the project are closely coordinated with those in project NET-02 of this program element and those in PE 0603764E, Land Warfare Technology.

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(U) The Maritime Systems project will identify, develop and rapidly mature critical advanced technologies and system concepts for the naval forces' role in today's network centric warfare concept. Naval forces play an ever-increasing role in network centric warfare because of their forward deployed nature, their unique capability to operate simultaneously in the air, on the sea and under the sea and their versatile ability to provide both rapid strike and project sustained force. The technologies developed under this project will capitalize on these attributes, improve them and enable them to operate with other network centric forces. Programs in this project are closely coordinated with those in project NET-01 of this program element.

(U) **Program Change Summary:** *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	121.613	136.899	176.855
Current Budget	118.538	134.944	174.276
Total Adjustments	-3.075	-1.955	-2.579
Congressional project reductions	-0.090	-1.955	
Congressional increases	0.000		
Reprogrammings	0.000		
SBIR/STTR transfer	-2.985		

(U) **Change Summary Explanation:**

FY 2005	Decrease reflects DOE transfer for P.L. 108-447 and the SBIR/STTR transfer.
FY 2006	Decrease reflects undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Decrease reflects minor shifts in program pricing and phasing.

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RDT&E, Defense-wide BA3 Advanced Technology Development	Network-Centric Warfare Technology PE 0603766E, Project NET-01

COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Joint Warfare Systems NET-01	31.813	55.024	78.605	82.750	84.657	85.657	89.657

(U) Mission Description:

(U) The objective of the Joint Warfare Systems project is to create enabling technologies for seamless joint operations, from strategic planning to tactical and urban operations. Joint Warfare Systems leverage current and emerging network, robotic, and information technology and provide next generation U.S. forces with greatly expanded capability, lethality, and rapid responsiveness. Critical issues facing this project are: (1) U.S. opponents utilizing systems that are flexible, robust, and difficult to neutralize; and (2) U.S. doctrine that limits the use of firepower to lessen the impact of operations on noncombatants. These problems are magnified in urban and semi-urban areas where combatants and civilians are often colocated, and in peacekeeping operations where combatants and civilians are often indistinguishable. Meeting these challenges places a heavy burden on joint war planning. Understanding opponent networks is essential so that creative options can be developed to counter their strategies. Synchronization of air and ground operations to apply force only where needed and with specific effects is required. This project supports all levels of the force structure including: (1) the strategic/operational level by generating targeting options against opponents' centers of gravity that have complex networked relationships; (2) the tactical/operational level by managing highly automated forces with tight coupling between air and ground platforms; and (3) the focused tactical level by developing platforms, which acquire targets of opportunity, cuing network-based analysis of likely enemy operations and developing warfighter tools, thus maximizing the presence of ground forces in Stability and Support Operational (SASO) environments.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Network Command	15.085	15.520	15.216

(U) The Network Command program leverages recent advances in network computing to dramatically improve collaboration among physically separate command posts. The program allows commanders and their staffs to share situation information, develop coordinated battle plans, generate and compare alternate courses of action, and assess likely outcomes, without conventional group briefings. Network Command

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builds on the paradigm established by the Command Post of the Future program, which demonstrated to commanders, working with voice-over IP and robust graphical collaboration software, a coherent understanding of a situation and operational plan without any face-to-face interactions.

- Command Post of the Future (CPOF) is currently deployed with multiple Army Divisions in support of Operations Iraqi Freedom (OIF). CPOF transitioned to the Army Program Executive Office Command, Control, and Communications Tactical (PEO C3T) in January 2006. This program created a system with radical new capabilities for improving decision making by operational commanders, providing dynamic tailored visualization and deep collaboration tools for improved situation awareness and course-of-action development and dissemination. The program has introduced a radical new concept for future command environments, namely, the elimination of the fixed command post that will be replaced by battle command on the move. Introduction of the tools developed under this program will allow future command structures to be mobile and distributed, thus enabling reduction of staff sizes and allowing commanders to operate effectively while on the move.

- The Multiuser, Adaptive Command Environment (MACE) program is based on advancements made under the Command Post of the Future (CPOF) program and will make collaborative tactical command more adaptive, cross-functional, and scalable. The program provides monitors in the collaboration environment to observe data traffic, identify patterns, and proactively move information through the system to more rapidly meet user's needs. MACE will monitor and adapt to user-system interactions, user-user collaborations, and changes in the operational environment. MACE allows users to be distinguished by their military function – intelligence, maneuver, fires, security, logistics – and tailors displays and communication modes to those functions. The system will also utilize profiles of the users that contain information about career, previous deployments and information display preferences to make the system more adaptable. Finally, the technology scales the environment from dozens to hundreds of workstations operating over a diverse set of tactical communication networks.

- The Network-Centric Situation Assessment program develops and deploys technologies to assess military situations at levels of interest above individual targets. The program uses all-source data to reconstruct unit organizations, mission relationships, logistics connections, and communications connectivity and analyzes data over time to infer movement, communication, and supply patterns. Within this context, capability analyses are provided and future courses of action are hypothesized. The objective is to understand potential capabilities and intentions of opposing forces. This effort provides greater understanding of opponents' force structures, capabilities, and operational practices, then enables commanders to sustain effects-based targeting rather than simple attrition strategies. The program

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provides a context for discovering vulnerabilities in opposing forces and provides cues for intelligence, surveillance, and reconnaissance planning, as it suggests areas of future enemy activity that merit intense scrutiny. Technologies are planned to transition to the U.S. Army Distributed Common Ground Station.

- The Joint Mission Rehearsal program integrates high-fidelity; mainframe-based combat simulations with situation assessment and planning tools. The objective is to allow rehearsal of joint missions, while participants are en route to operations or remain at their home stations. The program uses current situation data to: (1) provide initial conditions for the simulations, and (2) plan data to steer the dynamics of the simulations along the selected courses of action. The technology streams data from the simulations for display, then visualization systems are available to the prospective participants. The visualization permits the warfighter to interact with the simulation in a manner consistent with their anticipated role in the mission being rehearsed. The program delivers the capability to practice and fine-tune mission plans for joint military operations and enables commanders and staff to participate from their current location instead of a training facility, thereby reducing deployment needs while improving mission planning and effectiveness. Technologies are planned to transition to the U.S. Army Simulation, Training & Instrumentation Command.

(U) Program Plans:

– Command Post of the Future
  - -- Instrumented the deployed CPOF software to record data from field use.
  - -- Developed analysis tools to reconstruct information paths.
  - -- Designed system management tools to restructure information flows to meet decision needs.

– Multiuser, Adaptive Command Environment
  - -- Collected data from field operations describing information flows, timing, and decision patterns.
  - -- Identified patterns in those data corresponding to decision cycles and special tasks.
  - -- Develop techniques to proactively move information among workstations to reduce latency while maintaining consistency.
  - -- Scale the underlying technology to operate over both current and emerging tactical communications systems.

– Network-Centric Situation Assessment
  - -- Identify data fields available to a representative theater commander.

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-- Apply advanced link-analysis and pattern-matching technology to tactical data.
-- Evaluate technologies using real-world data.

– Joint Mission Rehearsal
  -- Enhance existing mission simulations to require "red cell and white cell" participants.
  -- Develop tools to rapidly assemble new mission scenarios from existing data sources.
  -- Develop techniques to infer data needed by the simulations.

	FY 2005	FY 2006	FY 2007
Precision Urban Combat Systems (PUCS)	4.000	8.423	11.165

(U) The Precision Urban Combat Systems (PUCS) is developing and validating advanced sensor, exploitation, networking, and battle management capabilities for joint dismounted forces in urban combat. The program includes detection and tracking of potential enemy targets, discrimination and identification of friendly versus enemy units, sorting of enemy from neutral and non-combatant personnel, coordination of sensing, maneuver, and fires, and continuous assessment of results. PUCS will utilize technologies including: smart networks of distributed imaging and non-imaging sensors; sensors with the capability to detect hidden human targets; improved 3D visualization systems, and multi-spectral discrimination systems that survey the battlefield for weapon activity and detect primary signatures. These capabilities will be developed within the framework of both legacy forces and expected future forces. The program will provide a set of prototype demonstrations of the capabilities in surrogate urban combat environments. Technologies are planned to transition to the U.S. Special Operations Command.

- The Robust, Persistent 3D Urban RSTA (reconnaissance, surveillance and target acquisition) program is providing situational awareness capabilities that will assist the warfighter in identifying and defeating enemy threats. This includes the ability to robustly detect and persistently track all-source targets in the highly cluttered, 3-dimensional urban landscape (outdoors and indoors). This program will demonstrate an innovative active radio frequency (RF) sensor network technology that uses broadband, short-pulse active RF technologies for low power precision radar and communications, exploits multi-static operation for robust 3-D target detection, localization and tracking, and provides distributed sensor fusion for target characterization.

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- The Smart Dust Sensor Networks Applied to Urban Area Operations Program will provide persistent staring reconnaissance, surveillance, and target acquisition (RSTA) of the three-dimensional urban battlespace using a dense network of ground sensors. The system concept consists of ubiquitous and inconspicuous low-power, small and easily concealed ground sensors distributed throughout the urban landscape. The program includes the development of ultra small sensor nodes for easy deployment and concealment in a crowded urban environment and data fusion algorithms to exploit the abundance of new information provided by a dense urban spatial network.

- The Networked Acoustic-Visual Imaging System (NAVIS) (formerly Head Mounted Alerting for Urban Operations) program will develop a networked weapon fire detection system using infrared sensor imagery fused with acoustic sensor information for precise localization of the source of weapon fire. The NAVIS system is a soldier-borne sensor array that moves with the dismounted unit, continually adapting to the dynamic threat situation in urban operations. The system exploits all available infrared and acoustic event data and correlates all observables from a multi-sensor, multi-node, networked array to minimize false alarms and maximize accuracy. The challenge of this initiative is to provide a moving networked sensor array, borne by dismounted warfighters, with near real-time visualization of the fused firing event data for immediate response and accurate pointing.

- The Exploiting Vibrations to Monitor Activities in Buildings program will develop procedures and sensors to characterize activity inside structures based on acoustic/seismic information. The types of information sought include number and location of personnel, foot traffic, operation of building mechanicals (ventilation, cooling, and heating; plumbing; etc.) as an indicator of human activity, operation of other machinery, door openings and closings, and speech. Algorithms that infer internal layout of the building from the pattern and location of these activities will be investigated along with the fusing of the information from other surveillance information gained by other sensing modalities.

- The Solar Blind UV Tagging, Tracking & Location (TTL) program will develop technologies and methodologies required to locate a vehicle in an urban environment. A compact and covert solar-blind Ultra Violet (UV) “tag” can be visually followed through non-Line-of-Sight (LOS) tracking by a UV camera. This program is critical to tracking vehicles containing persons of interest through a difficult visual tracking urban environment. Phase one of the project involves concept of operations development, modeling, and validation. Ground-based field tests will be performed with DayCor II UV cameras to assure strength of detection and non-LOS isolation of the tag. Following successful ground tests, the second phase involves procurement and integration of an airborne platform to validate concept of operations for aerial tracking of the source tags. The primary technical obstacles that must be overcome to develop the tracking

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mechanism are the development of a powerful enough UV source to facilitate detection through non-LOS scattering at a safe hovering altitude. The tag must be both small enough to be unnoticeable and big enough to support a battery supply for reasonable power life. In addition, this UV source must be detectable and distinguishable from other sources by the camera. The UV camera must be able to queue the observer and allow for reliable geo-tracking of a tag through joystick controls and visual detection. This capability will be transitioned to Air Force and Army Combatant commands for use in ground-based and low-altitude airborne reconnaissance platforms starting in FY 2008.

(U) Program Plans:

– Robust, Persistent 3D Urban RSTA
  - -- Collect Ultra-wide band target and background signatures.
  - -- Develop and demonstrate technologies to separate targets from background.
  - -- Test at a representative Military Operations on Urban Terrain (MOUT) site.

– Smart Dust Sensor Networks Applied to Urban Area Operations
  - -- Develop miniaturized sensors based on Network Embedded Systems Technology (NEST) concept.
  - -- Develop and demonstrate technologies to separate targets from background.
  - -- Develop battlefield activity alert logic.
  - -- Conduct demonstration at a representative MOUT site.

– Networked, Acoustic-Visual Imaging Systems (NAVIS)
  - -- Develop dynamic network sensor processing algorithms.
  - -- Develop fusion emulator for post processing data analysis.
  - -- Conduct testing and data collection under controlled motion conditions and various conditions.
  - -- Develop brassboard processor with sensor and fusion processing algorithms.
  - -- Conduct live-fire testing under controlled motion conditions in realistic urban conditions.
  - -- Develop real-time fusion and visualization software.
  - -- Design and develop a man-wearable NAVIS prototype.

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– Exploiting Vibrations to Monitor Activities in Building
  -- Collect acoustic/seismic data from a set of sample buildings.
  -- Develop and demonstrate technologies to separate targets from background and summarize activity.
  -- Demonstrate at a representative MOUT site.

– Solar Blind UV Tagging, Tracking & Location
  -- Develop conceptual design and CONOPS meeting objective system performance requirements.
  -- Ground-based demo verifying signal strength and non-LOS tracking.
  -- Develop airborne testbed and conduct flight demo.

	FY 2005	FY 2006	FY 2007
Effects Based Network Targeting	3.600	4.062	4.500

(U) The Effects Based Network Targeting program develops technology to identify, determine vulnerabilities, target, and anticipate workarounds in enemy networks. These techniques use all-source information to continuously update models of urban networks (e.g., transportation, energy). An aim is to elicit operational objectives for urban interventions, expressed in terms of desired and undesired effects. The technology will use these objectives to find vulnerabilities in the networks, then nominating targets for prosecution so as to maximize desired effects while minimizing undesired effects. Further, the program develops techniques for predicting those observables that will rapidly identify an opponent's response when several courses of action are available. The program enables warfighters to develop effects-based target sets at forward command nodes and provides commanders a means to anticipate and counter an opponent's workarounds. Finally, Effects Based Network Targeting minimizes undesired effects by anticipating downstream consequences and selecting targets with low risk of collateral damage, permitting targeting operations to proceed, even within restrictive rules of engagement. Technologies are planned to transition to the U.S. Strategic Command.

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(U) Program Plans:

- Develop tools to: (1) extract relevant information from source data (especially signals, text, and imagery); (2) correlate that information to existing models; (3) update the models while resolving conflicts among sources; and (4) analyze the overall effect of newly discovered changes.
- Design tools to analyze networks, singly and in combination, in order to identify vulnerabilities to predict effects of candidate interdictions.
- Demonstrate selected tools on real-world cases, validating against historical and natural situations.

	FY 2005	FY 2006	FY 2007
Confirmatory Hunter Killer System	9.128	8.741	6.481

(U) The Confirmatory Hunter-Killer System program is developing a low-cost, expendable loitering weapon/unmanned air vehicle for deployment in urban environments. The objective is to provide localized surveillance against limited (one or two) specific targets. The vehicle employs two on-board electro-optic/infrared sensors and downlinks data to a control device containing target designation capability to confirm engagement with a human operator. The program provides image-based target acquisition capability, permitting suppression of non-emitting targets, time-critical targets, emerging targets, and threats to lines of communication and other delimited regions. The program enables suppression of targets emerging from underground or concealed facilities. The Confirmatory Hunter Killer System is planned for transition to the Army, at the conclusion of Phase II anticipated to be completed by the end of FY 2007.

(U) Program Plans:

- Characterized component capabilities (platform, sensor, and onboard automatic target tracking and data links).
- Developed and analyzed alternative designs, using high-fidelity simulation and analysis tools in a variety of joint mission contexts.
- Selected combinations of components that achieved the most effective system capabilities.
- Develop a brass-board platform with compact hand-launcher; verify sensor, automatic target tracking, and data link performance.
- Tailor and improve component capabilities to reduce manufacturing cost, while preserving effectiveness.
- Construct prototype vehicles and conduct field tests.

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	FY 2005	FY 2006	FY 2007
Sensing and Patrolling Enablers Yielding Enhanced Security (SPEYES)	0.000	5.633	7.631

(U) The Sensing and Patrolling Enablers Yielding Enhanced Security (SPEYES) program provides technologies for Stability and Support Operations (SASO) to enhance the capabilities of our current ground forces in Iraq and Afghanistan. The first program phase evaluates and inserts mature advanced ground-based C3I technologies for three problem areas (Fixed Site Security, Patrolling, and Cordon & Search), seeking to effect a significant force-multiplier improvement through transformational Tactics, Techniques, and Procedures (TTPs). Key Component Technologies include: 1) WASP Micro UAV, 2) Eye Ball R1 Throwable Camera, 3) Leave Behind Intrusion Detection Sensor, 4) SPEYES Handheld PDA Device, and 5) Vehicle Weight Analysis Software and Video/EOD Underbody Sniffers. Later program phases will expand SPEYES technologies to develop a deeper understanding of team cooperation and culture in dynamic coalition and multi-national team settings. This work will focus on the development of two cultural advisors, one for the soldier on patrol and a second cultural advisor for command staff and strategic-level military personnel, which will incorporate extensive cultural knowledge for interacting with civilian government officials, military coalition partners and multinational teams. The technology is planned for transition to the Army and Marine Corps.

(U) Program Plans:

- Develop/procure prototypes of selected SPEYES technologies.
- Plan, conduct, and evaluate appropriate training events with selected Marine and Army deploying units to determine employment CONOPS.
- Following ruggedization of selected prototypes, provide deployable technology for movement to theater.
- Develop local and regional cultural databases and mappings of cultural dynamics of behavior.
- Develop and evaluate an information gathering and retrieval capability for patrolling soldiers.
- Evaluate system functions for both individual and staff level functions in culturally specific environments at the National Training Center.

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	FY 2005	FY 2006	FY 2007
Multi Dimensional Mobility Robot (MDMR)	0.000	8.000	10.240

(U) The MDMR program will investigate concepts using serpentine mobility to achieve new ground robot capabilities for search and rescue applications. The MDMR system will traverse complex urban terrain for search and rescue. Examples of the capability include: overcoming obstacles that are a significant fraction of its length, crossing slippery surfaces, and climbing steep slopes. The MDMR platform will be able to support a variety of search missions in hazardous environments such as urban rubble piles. To achieve such a degree of mobility, design concepts must address system challenges such as: on board power management; situational awareness; complex terrain navigation; and system controls.

(U) Program Plans:

- Demonstrate serpentine mobility from a base level approach.
- Integrate the robotic system and user interface control.
- Develop and test tele-operation control.
- Perform rigorous testing to characterize system performance and spiral new technology developments into the existing platform.
- Transition platform to search and rescue users and demonstrate new capabilities.

	FY 2005	FY 2006	FY 2007
Network Centric Logistics	0.000	4.645	6.972

(U) The Network-Centric Logistics program will develop, integrate and evaluate technologies to control and optimize the overall supply flow and inventory strategies for logistics support. The technology enables logistics flows both horizontally and vertically across the joint battlefield, allowing different commodity flows to operate as complex adaptive networks, rather than as fixed logistics chains. By viewing the supply situation as a network, with feedback as well as feed forward paths, these technologies increase responsiveness to dynamically changing needs within low echelon operating areas. Key technologies include: (1) in-inventory sensors to determine supply usage rates within mission context, (2) predictive demand models to forecast emerging needs based on a unit's operational plan, (3) agent-based negotiation protocols with provable

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stability, and (4) transport planning technology to enable unconventional commodity flows. Technologies are planned to transition to the U.S. Army and U.S. Transportation Command.

(U) Program Plans:
- Extend existing logistics simulations to include nontraditional transport mechanisms and their coupling to combat operations.
- Develop adaptive demand models driven by historical material expenditure rates and predictive operations plans.
- Implement functional models of new inventory sensing technologies.
- Define an agent-based computing architecture, aligning agents with decision nodes in a future logistics organization.
- Develop decision protocols for insertion into the agents.

	FY 2005	FY 2006	FY 2007
Human-carried Explosive Detection Stand-off System (HEDSS)	0.000	0.000	3.000

(U) Insurgent and terrorist elements are increasingly relying on human carried explosives because they are nearly impossible to detect visibly. The goal of the Human-carried Explosive Detection Stand-off System (HEDSS) program is to develop a system that can rapidly identify human-carried explosives (HCEs) at a stand-off range between 50 and 150 meters. While alternative technologies exist for HCE detection, they necessitate close-in sensing, are expensive and require extended processing times. Successful development of a HEDSS with detection ranges of 50 – 150 m will provide reliable protection for deployed forces from suicide bombers by allowing enough time and space to interdict bombers before they cause maximum damage.

(U) Program Plans:
- Conduct proof-of-concept experiments and perform system level analysis designed to validate key technical assumptions and identify major system design parameters.
- Design components and system.
- Build and integrate system and conduct lab experimentation.
- Conduct extensive field testing of the system under realistic threat conditions.

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	FY 2005	FY 2006	FY 2007
Federated Object-level Exploitation (FOX)	0.000	(6.885)	10.400

(U) Federated Object-level Exploitation (FOX) thrust will provide a new set of geospatial intelligence products, continuously updated and maintained in a form that ensures their consistency across both product elements (digital elevation models, traditional maps, 3D structure models, census summaries, and directories) and spatial nodes (coarse resolution country data for economic analysis to fine resolution building data for platoon-level combat operations). Included programs will combine techniques including model-based image analysis (both object recognizers and change detectors), symbolic correlators (both temporal and spatial), and emerging cognitive methods to identify changes to objects, addresses, names, and functions of natural and man-made structures. These algorithms will be scaled to operate on data streams including full-motion video, ladar, text, and tabular data, in addition to conventional geospatial imagery. Federated algorithm architectures will be explored to achieve scalability through spatial, temporal and ontological partitioning. FOX technologies are planned for transition to the National Geospatial-Intelligence Agency. FOX transfers from PE 0603762E, project SEN-02 in FY 2007.

- The Auto Metadata Extractions effort will build a system to automatically (with no man-in-the-loop) extract metadata from 400 terabytes of multi-sensor all-source imagery, Moving Target Indicator (MTI) and signals per day. Extracted metadata will include both platform generated information (classical metadata) and algorithmically extracted features and internals. The extracted metadata will be (a) produced in a unified framework, and (b) sufficiently semantically rich to support both semantic information fusion and development of multi-dimensional predictive models. The system will provide all of the fundamental extracted data required for advanced exploitation technology development.

- The Exploitation Language Technology for GeoINT program will build a system to extract and linguistically confirm terms and labels of geographic significance from graphical, textual and audio sources. Develop the technology to associate and verify the extracted information against features extracted from imagery. Both extraction and association will be performed against and across multiple languages. Develop necessary database and query technology to support rapid access and search against the developed corpus. Develop necessary database and query technology to support a wide range of GeoINT specific concepts, e.g., feature classes, complex distance calculations, and boundaries.

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- The All Things Repository effort will develop a system capable of ingesting 400 terabytes of multi-sensor all-source imagery, Moving Target Indicator (MTI) and signals per day. Build a fully automated metadata and features extraction framework to process all incoming data. Develop the distributed very-large database technologies required to provide both the raw sensor data and extracted features data to a multi-level exploitation user community which consists of both human users and automated agents. Develop work-flow aware data transformation, data aggregation and data caching technologies which will rapidly provide the user with access to the correct subset of the data rapidly and at appropriate bandwidth.

(U) Program Plans:

– Auto Metadata Extractions
  -- Develop a unified processing infrastructure for the generation of metadata from all-source.
  -- Demonstrate a unified semantic representation of metadata generated from all-source.
  -- Demonstrate the collection/conversion of platform generated metadata into the unified representation.
  -- Demonstrate generation of metadata from all-source imagery into unified representation.
  -- Demonstrate generation of metadata from MTI into unified representation.
  -- Demonstrate generation of metadata from signals into unified representation.
  -- Demonstrate generation of metadata from fusion of prior metadata into unified representation.

– Exploitation Language Technology for GeoINT
  -- Demonstrate extraction of geographic terms, e.g., city names, and their association with geolocations from textual sources.
  -- Demonstrate extraction of geographic terms, e.g., street names, and their association with geolocations from graphical sources.
  -- Develop a multi-lingual ontology of geographic language.
  -- Demonstration extraction of geographic language from graphical, textual and audio sources.
  -- Demonstrate multi-lingual queries of geographic language from a large collection of extracted terms.

– All Things Repository
  -- Demonstrate a multi-source co-registered database over a village sized site.
  -- Demonstrate unified access in a single query to multiple spatial and temporal data types.
  -- Demonstrate incorporation of automated feature extraction into high volume data flow.

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-- Experimentally determine where data volume causes system failures.
-- Demonstrate solutions to very large data volume induced failures.
-- Demonstrate data selection and summarization based on prior work-flows and access.

	FY 2005	FY 2006	FY 2007
Acoustic Landmine Detection System	0.000	0.000	3.000

(U) The Acoustic Landmine Detection System will develop new acoustic and detection technologies to overcome deficiencies in locating landmines. These systems will include the use of highly directional sound sources to cause the mines to vibrate at sufficient amplitude to be detected with a wide field-of-view laser interferometer. This approach will provide a system with the high probability of detection and low false-alarm rate required to meet the needs of the warfighter. Initial efforts will include field measurements at a landmine detection research facility to determine the tradeoffs among various detection technologies. These experiments will determine the system performance capabilities needed to support troop advance rates >30km/hour in hostile terrain. The systems developed under this effort will be tested against a wide variety of mine types and soil properties to support operations under a wide range of conditions. Upon successful development of the initial and objective systems, the capabilities will be transitioned to the Army and Marine ground forces for the development and employment of operational systems starting in FY 2010.

(U) Program Plans:

– Develop conceptual system designs meeting objective system performance (e.g., scan rates commensurate with >30km/hr convoy speed).
– Perform risk reduction technology development for the acoustic source and vibrometric sensor.
– Conduct brassboard demo of prototype.
– Construct form factor prototype and verify performance.
– Transition systems technology to Army and Marines for incorporation into future force structures.

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

- Not Applicable.

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RDT&E, Defense-wide BA3 Advanced Technology Development	Network-Centric Warfare Technology PE 0603766E, Project NET-02

COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Maritime Systems NET-02	30.059	32.834	34.753	30.903	30.839	30.839	30.839

(U) Mission Description:

(U) The objective of the Maritime Systems project is to identify, develop and rapidly mature critical advanced technologies and system concepts for the naval forces' role in today's network centric warfare concept. Improvements in communications between and among submarines, surface ships and naval aircraft have allowed these forces to operate seamlessly with each other and with other Service's network centric systems. Naval forces will play an ever-increasing role in network centric warfare because of their forward deployed nature, their unique capability to operate simultaneously in the air, on the sea and under the sea and their versatile ability to provide both rapid strike and project-sustained force. The technologies developed under this project will capitalize on these attributes, improve them and enable them to operate with other network centric forces. This project funds the Mobile Undersea Distributed System (MUDS) program, the Jet Blast Deflector program, the Non Linear Dynamics for Anti-Submarine Warfare (ASW), and the Tango Bravo (formerly Reduced Size, Affordable Submarines) technology demonstration program.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Mobile Undersea Distributed Systems (MUDS) Program	18.109	18.834	16.753

(U) The Mobile Undersea Distributed System (MUDS) program goal is to enhance operations in the littorals to counter asymmetric threats posed by diesel submarines and other forces operating in the littorals, by distributing countering capabilities throughout a complimentary and networked system of sensors and platforms. The network-centric MUDS program includes the Sea Sentry effort, the Persistent Ocean Surveillance effort, Warfighting in the Littoral effort, the Aluminum Combustor effort, the River Eye effort and the Compact Aperture Ranging Passive Sonar effort.

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(U) The Sea Sentry effort investigated an underwater, distributed sense and effect system to detect and localize difficult undersea targets such as submarines employing advanced air-independent propulsion technologies. Using covert, mobile, and energy-efficient vehicles, the tactical gain available from the collective intelligence behavior of a swarm of individual agents was explored. This effort identified technologies in the areas of agent-based autonomous control; vehicle navigation; high data rate/low-power underwater communications; network management and optimization; sustainable energy concepts; and low power sensing/signal processing enabling covert persistent underwater surveillance in denied areas.

(U) The Persistent Ocean Surveillance program will combine geolocation techniques such as the global positioning system with station keeping and intra-sensor communication technologies to provide long-term station keeping ocean environment sensing buoys. These technologies, when applied with state-of-the-art undersea warfare sensors, will result in a floating field of smart sensors capable of observing the undersea environment in an area, including the presence of submarines and other undersea vehicles. A range of technologies will be considered including those that rely on the local environment (such as wind, ocean waves, solar energy, temperature differentials, etc.) for their power, miniature geolocation technologies, and technologies for sensor data storage, transmission, and intra-field communications. Persistent Ocean Surveillance-Station Keeping technology is planned for transition to the Navy in FY 2008.

(U) The Warfighting in the Littoral effort is the vehicle for investigating and developing technologies recommended by the joint DARPA/Navy Littoral Naval Force Architecture Study that explored future concepts and potential technologies for rapid access and successful operation in contested areas defended by forces ashore, mines, submarines, small craft, and anti-ship missiles. The technologies developed will directly affect the ability of Naval Forces to accomplish missions in the world's littorals—some may involve significant technical obstacles that, if overcome, would lead to dramatic improvement in capability. Potential transition targets include a broad spectrum of existing and future naval programs. DARPA established an MOA with the Marine Corps for this program in October 2004.

(U) The Aluminum Combustor program seeks to develop an energy-dense air-independent underwater power source as a potential propulsion system for underwater vehicles. This program will optimize the design for a small combustor and develop the auxiliary power system components needed to control and sustain operations. In addition to the combustor, the aluminum fuel feed subsystem, aluminum-steam separator subsystem; and closed loop control subsystem will be designed, built, and tested and integrated with a turbine in order to successfully demonstrate a power system in a laboratory environment. The Aluminum Combustor technology is anticipated to transition to the Navy in FY 2008.

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(U) Early entry maritime forces need maps of morphology, water depths, and currents in complex riverine/estuarine environments for mission planning and execution. This information is critical for route planning, sensor placement, rendezvous determination, vulnerability assessments, and for determining objective assault engagement/disengagement strategies. For uncharted and/or denied areas, present methods are inadequate for obtaining the necessary information. Reliable remote sensing methods do not exist that produce bathymetry and water current data in waters that are sediment laden (bottom is not visible) and/or sheltered (swell and significant wind waves are not likely). The River Eye effort will provide a new capability to predict or assess, in real time, river and estuary conditions to enable special operations mission planning and execution. New techniques will be developed to indirectly determine current speed and direction by remotely sensing advection of scene features. Using advanced modeling techniques, indirectly sensed current data will be used to extract bathymetry data. Forward circulation models will use the bathymetry data to predict future currents and water heights in a mission planning decision support tool. The River Eye effort is anticipated to transition to the Navy and National Geospatial-Intelligence Agency in FY 2010.

(U) The ability of U.S. Navy submarines to maintain situation awareness and tactical advantage in shallow water is challenged by difficulty to safely deploy the highest-capability acoustic sensor, the long towed array. The Compact Aperture Ranging Passive Sonar (CARPS) effort explored the feasibility of a towed array capability in a compact hull or dome-mounted sonar aperture. CARPS sought to exploit non-acoustic shear waves induced in the material of a small aperture by external acoustic energy. The program evaluated practical beamforming techniques, the effect of acoustic and non-acoustic noise on performance, and the ability to resolve multiple acoustic sources.

(U) Program Plans:

- Mobile Undersea Distributed Systems
  - Continue investigation into novel communications and networking concepts.
  - Explore concepts to reduce platform infrastructure and, ultimately, the cost of future design and production of submarines.

- Sea Sentry
  - Assessed concepts employing swarms of undersea vehicles with acoustic and non-acoustic sensing modalities for detecting and tracking submarines with air-independent propulsion (AIP) systems.
  - Assessed performance of acoustic and electric field sensors on undersea gliders.

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- Persistent Ocean Surveillance
  - Explored the scientific/engineering issues associated with station keeping.
  - Demonstrated feasibility of using nanofluidic technology with moving magnets in linear generated configuration to harvest wave energy.
  - Characterized ferrofluidic material and developed electromagnetic models.
  - Develop a long endurance tactical sized ocean surveillance buoy using exploitable local environmental effects for station keeping.
  - Demonstrate performance at sea.

- Warfighting in the Littoral

  Generate capabilities and identify technologies of interest to include:
  - Technologies that allow dispersed, maneuvering forces to conduct network-enabled operations at extended distances from over the horizon.
  - Technologies to increase the warfighter's situational awareness.
  - Technologies to increase shared situational awareness among adjacent units as well as among higher and lower echelons of command.
  - Technologies to allow small units to apply joint precision fires.
  - Technologies to enhance the survivability and biology-oriented performance of the warfighter.
  - Technologies to enable the sustainment of widely dispersed units (squad to battalion-size) over extended periods.
  - Technologies to reduce the logistics burden of combat, combat support and combat service support forces, such as alternate fuels and power sources, reduced diameter weapons and liquid propellants.
  - Technologies to enhance the personal and collective mobility of ground forces.

- Aluminum Combustor
  - Conducted several test firings of the Vortex Combustor system.
  - Conducted analysis and performance evaluation.
  - Demonstrated slag free, 15-minute endurance runs of a redesigned Aluminum Combustor engine.

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- Design and fabricate the low Hp combustor, aluminum fuel feed subsystem, aluminum-steam separator subsystem; and closed loop control subsystem.
- Integrate and test the power system in the laboratory.

• River Eye
  - Assessed sensor modalities, and conducted field experiments in mixed estuary environments establishing proof of concept.
  - Conduct analysis on existing circulation models to determine model sensitivity to bathymetry, winds, and fresh water inflow.
  - Develop inverse model for extracting bathymetry from indirectly sensed currents.
  - Integrate sensor(s) onto airborne platform, conduct instrumented data collections in well-mixed and stratified environments, and complete prototype mission planning system.
  - Conduct real time at sea demonstration.

• Compact Aperture Ranging Passive Sonar (CARPS)
  - Investigated the concept through analysis and simulation.

	FY 2005	FY 2006	FY 2007
Jet Blast Deflector	2.950	1.000	1.000

(U) The Jet Blast Deflector program is an outgrowth of the DARPA structural materials program funded in PE 0602715E. The program will use multifunctional materials to construct a passively cooled jet blast deflection that increases reliability and meets weight reduction requirements for current and future classes of aircraft carriers. A Memorandum of Agreement was signed (January 2004) with the Navy's PEO (Aircraft Carriers) that agrees to, based on a successful sub-scale concept demonstration by end of FY 2005, full scale demonstration of prototype panel performance at Naval Air Warfare Center, Aircraft Division Lakehurst and a use decision for CVN21.

(U) Program Plans:
- Demonstrate that multifunctional materials can reduce weight by over 50% and will save operations and support costs by 26%.
- Test and validate performance and savings.

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	FY 2005	FY 2006	FY 2007
Non-Linear Dynamics for ASW	0.000	2.500	0.000

(U) The field of nonlinear dynamics has matured sufficiently to allow applications to nonlinear and non-stationary signal processing problems. Nonlinear beamforming approaches will be applied to the Navy's Advanced Extended Echo Ranging (AEER) airborne Anti Submarine Warfare (ASW) concept to enhance the effectiveness of active acoustics in the littoral ASW environment by improving the ability to detect weak signals in the presence of noise, interference, and reverberation.

(U) Program Plans:

- Develop system requirements for the nonlinear Air Deployable Active Receiver (ADAR) beamformer.
- Develop analytical formulation of the nonlinear ADAR beamformer array dynamics.
- Develop high fidelity time series simulation data for evaluating nonlinear beamformer performance.
- Develop quantitative assessment of potential improvement for realistic environments.

	FY 2005	FY 2006	FY 2007
Tango Bravo (formerly known as Reduced Size, Affordable Submarines)	9.000	10.500	17.000

(U) Based on the results of the DARPA/Navy Submarine Design Study, the Tango Bravo technology demonstration (formerly known as the Reduced Size, Affordable Submarines) program is exploring design options for a reduced-size submarine with equivalent capability of the VIRGINIA Class submarine. The implicit goal of this program is to reduce platform infrastructure and, ultimately, the cost of future design and production of submarines. The program is a collaborative effort to overcome selected technological barriers that are judged to have a significant impact on submarine platform infrastructure cost. DARPA and the Navy, under Memorandum of Agreement jointly formulated technical objectives for critical technology demonstrations in: (1) shaftless propulsion, (2) external weapons stowage and launch, (3) conformal alternatives to the existing spherical sonar array, (4) radical ship infrastructure reduction technologies that eliminate or substantially simplify hull, mechanical and electrical systems, and, (5) automated attack center technologies to reduce crew manning. The Tango Bravo program is anticipated to transition to the Navy in FY 2009.

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(U) A substantial challenge faced by the Navy submarine force is communications at speed and depth (CatSD). With the advent of network centric warfare, the submarine's evolving tactical missions require both timely transmission and receipt of tactical intelligence and operational directives. When mission effectiveness requires the submarine to operate below periscope depth, the challenge to communicate greatly affects the submarine's contributions to the operational commander. This program will develop an expendable communications device/system that would enable high bandwidth communications at tactically significant speeds and depths while minimizing probability of detection. It combines a propelled tow body with a hybrid, inflatable kite to hold an antenna aloft for extended periods. The tow body would be connected to the submarine by a cable tether, which supplies electrical power for tow body propulsion and communications signal amplification. The propelled tow body will be designed to deploy from the signal ejector of any U.S. submarine.

(U) Program Plans:

- Tango Bravo
  - Develop shaftless propulsion concepts and demonstrate required technologies at an appropriate scale to validate key aspects such as system size and weight, propulsive efficiency, and acoustic and electromagnetic signatures, including predictive capability.
  - Develop external weapons stowage and launch concepts and conduct an integrated demonstration of the critical technologies required to meet launch hydrodynamics requirements while providing a safe stowage environment for a Mk48 ADCAP torpedo outside the pressure hull.
  - Investigate maintenance and health issues associated with prolonged weapon stowage away from manned access.
  - Analyze modeling to evaluate acoustic and shock performance requirements.
  - Develop and demonstrate a radical ship infrastructure reduction concept that relies on electric actuation of the rudder and stern planes instead of traditional hydraulic- mechanical movement of the ship's control surfaces.
  - Demonstrate that employment of the proposed concept in an "X" (vice cruciform) configuration of the stern planes and rudder provides sufficient control authority such that the retractable bow plane system would not be required.

- Expendable Communications at Speed and Depth (CatSD) System
  - Develop guidance and control technology for propelled, inverted tow body towing.
  - Develop hybrid balloon kite antenna sub-system.
  - Design and procure tether cable system.

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– Conduct towed and ejected demonstrations.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	196.594	186.746	205.519	221.442	219.805	205.919	190.919
Surveillance and Countermeasures Technology SEN-01	61.852	58.957	62.436	72.936	74.342	58.956	44.956
Sensors & Exploitation Systems SEN-02	134.742	127.789	143.083	148.506	145.463	146.963	145.963

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

(U) The Sensors Technology program element is budgeted in the Advanced Technology Development Budget Activity because it 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.

(U) The Surveillance and Countermeasures Technology 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. Timely surveillance of enemy territory under all weather conditions is critical to providing our forces with tactical information needed to succeed in future wars.

(U) Additionally, this project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats. These technology developments are embodied in the following programs: Rescue Transponder; NUCTRAC; Visibuilding; Surveillance and Threat Neutralization in Urban Environments; Counter Underground Facilities; Hostile Fire Indicator; RF MEMS Improvement; Low Cost Cruise Missile Defense; Integrated Sensor Is Structure (ISIS); Speckle Exploitation for Enhanced Reconnaissance (SEER); Digital Radio Frequency Tag; and Wireless Vibration Sensor Initiative.

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(U) The Sensors and Exploitation Systems project develops and demonstrates advanced sensors, and exploitation technologies. These efforts provide warfighters with situational awareness and precision target identification. The project is driven by four needs: (1) countering camouflage, concealment and deception (CC&D) of mobile ground targets; (2) providing near-real-time, semi-automatic exploitation of wide-area moderate- and high-resolution imagery; (3) obtaining real-time, accurate battle damage assessment; and (4) accomplishing robust, precise identification, precision fire control tracking and engagement of high value targets. These needs are addressed by the following thrusts: Advanced Exploitation Systems Technology; Network Centric Sensing and Engagement; Advanced Optical Sensor Technology; and Advanced Radar Sensor Technology.

(U) Program Change Summary: *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	201.917	189.452	200.088
Current Budget	196.594	186.746	205.519
Total Adjustments	-5.323	-2.706	5.431
Congressional program reductions	-0.155	-2.706	
Congressional increases	0.000		
Reprogrammings	0.000		
SBIR/STTR transfer	-5.168		

(U) Change Summary Explanation:

FY 2005	Decrease reflects the DOE transfer for P.L. 108-447 and the SBIR/STTR transfer.
FY2006	Decrease reflects undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Increase reflects minor shifts in program pricing and phasing.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Surveillance and Countermeasures Technology SEN-01	61.852	58.957	62.436	72.936	74.342	58.956	44.956

(U) Mission Description:

(U) This project funds sensor efforts that will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability and battle damage assessment. Timely surveillance of enemy territory under all weather conditions is critical to providing our forces with the tactical information needed to succeed in future wars. This operational surveillance capability must continue to perform during enemy efforts to deny and deceive the sensor systems, and operate, at times, in a covert manner. This project will exploit recent advances in multispectral target phenomenology, signal processing, low-power high-performance computing, and low-cost microelectronics to develop advanced surveillance and targeting systems. In addition, this project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Counter-Underground Facilities	18.000	14.000	20.436

(U) Underground Facilities (UGFs) are being increasingly employed to hide a variety of tactical and strategic functions, including command and control, leadership escapes and hides, missile and artillery protection, and activities associated with the manufacture and storage of weapons of mass destruction. The Counter-Underground Facilities (CUGF) program is developing technologies to both find and characterize UGFs: identification of facility function, pace of activity, pre-attack status of the facility, trans-attack activities and post-attack status. Techniques are being developed to determine locations of critical systems (power, water, airflow and exhaust vents), orientation and depth of structure, and pre-strike and post-strike changes in the substructure resulting from attack.

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(U) This program began by developing validated phenomenological models for a range of underground facilities (UGF) signatures: acoustic, seismic, electromagnetic (EM), chemical, multi/hyperspectral, and gravity/gravity gradient. These models enable the evaluation of multiple sensor/targeting concepts, and drive requirements for highly sensitive, advanced sensors, which operate at very low frequencies in order to reach deeply buried structures. One concept under development, the CUGF Unattended Ground Sensor System (CUGSS), will demonstrate the use of multiple, networked ground nodes of multi-phenomenological sensors (EM, acoustic, seismic) for UGF monitoring and target characterization. Another element, Effluents for Vent Hunting, has evaluated the feasibility of finding vents from stand-off locations by exploiting the spatial, spectral, and temporal characteristics of the exhaust plumes. The Low-Altitude Airborne Sensor System (LAASS), will demonstrate the use of airborne EM, acoustic, and gravity sensors to rapidly find UGFs and map out their backbone structure. Techniques are also being developed for finding and mapping traces and portals of small tunnels used for movement among large facilities or buildings, and for surreptitiously crossing borders and security boundaries. The CBT (Cross-Border Tunnel) program is using seismic and electromagnetic tomographly to detect and localize small tunnels. The RITA (Remote Interconnected Tunnel Assessment) program is using stand-off hyperspectral sensing to determine portals and vents that are connected by tunnels underground. Other potential technologies to be included are precision thermal imaging and active surface seismic and electromagnetic approaches. These are particularly useful for small, relatively shallow, unimproved tunnels.

(U) To support the demonstrations of these concepts, the CUGF program is also developing or modifying E-field, B-field, quantum, acoustic, and gravity-based sensors and enhancing navigation communications and signal-processing systems and technologies as necessary to meet the node-localization, communications and data-exfiltration requirements. The CUGF technologies are planned for transition to the United States Special Operations Command, the Defense Intelligence Agency, the Army and the Air Force in the FY 2008 time frame.

(U) Program Plans:

- Completed signature data collection and characterization of geophysical site properties of UGFs.
- Completed model validation for seismic, acoustic, electromagnetic and effluent signatures and backgrounds and for effluent modeling tools.
- Evaluated concepts for effluent-based vent hunting and cave exploration, and developed candidate sensor designs for effluent-based characterization.
- Demonstrated functional prototype of multi-mode/multi-node ground sensor system, using clutter-limited sensors.
- Demonstrated feasibility of rapid, airborne surveillance and mapping of UGF structures.

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- Developed component technologies for deployable systems, including low-mass coupling of seismic vibration sensors, site-adaptive non-line of sight communications, and improved deployable EM and gravity sensors.
- Conducted gravity gradiometer sensor and clutter performance measurements.
- Determined limits of performance of LAASS vs. altitude, sensor performance, and dwell time on target.
- Develop designs and performance predictions for prototype LAASS sensor payloads (EM, acoustic, and gravity) for UAV platform.
- Integrate LAASS sensor payloads onto low-altitude UAV platform and develop optimum flight pattern strategy.
- Demonstrate LAASS prototype system in rural and urban environments.
- Investigate the use of quantum sensing phenomena.
- Develop and demonstrate small tunnel finding, localizing, and endpoint mapping capabilities in the CBT (Cross-Border Tunnel) and RITA (Remote Interconnected Tunnel Assessment) programs.

	FY 2005	FY 2006	FY 2007
Visibuilding (Formerly Building Structure Activity and Assessment)	5.000	5.000	9.000

(U) The Visibuilding program will develop technologies and systems for new surveillance capabilities of buildings, to detect personnel within buildings, to determine building layouts, and to locate weapons caches and shielded enclosures within buildings. Radar signals can be used to image static structures directly. Doppler processing of radar signals can be used to find moving personnel within a building and also allow mapping of building pathways and stairways by monitoring traffic through buildings. Doppler resonances of the building structure may also provide relevant mapping information and indications of floor loading. Multipath and propagation effects can be modeled and iteratively compared with hypotheses of building structures to provide 3-D building maps and large concentrations of metal materials like weapons. This program will develop techniques to inject and recover probing waveforms and to unravel the complicated multipath in the return signals, to enable the mapping and characterization of buildings. In addition, it will demonstrate technologies to monitor the integrity of building envelopes, to identify a breach of previously sealed/secured buildings and to identify previously hidden above and below-ground connections between buildings; approaches include pressure and power-line monitoring as well as the use of tracer gases deployed by hand or by robotics, such as multiple miniature search and rescue probes consisting of simple ball-like robots with rolling and hopping capability for building and rubble penetration. Transition to the Army’s PEO Soldier and United States Special Operations Command is planned for FY 2008.

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(U) The Radar Scope program is a quick-response effort to provide pre-production prototypes of hand-held through-wall personnel detection radar. It will be able to sense through common wall materials to detect potential enemies before warfighters enter a room or building. The final product will be a small sensor with a simple interface that will weigh less than two pounds including batteries. The unit will detect individuals through typical non-metallic wall materials (e.g., concrete, concrete block, adobe, wallboard, plywood, etc.) up to twelve inches thick. Transition to the Army Rapid Equipping Force for testing in theater is planned for FY 2006, with eventual transition to PEO Soldier.

(U) Program Plans:

- Visibuilding
  - -- Evaluate candidate designs for wall-penetrating technologies for building layout and combatant localization.
  - -- Evaluate candidate technical approaches for monitoring building envelope integrity.
  - -- Evaluate technical approaches for building interconnects detection and assessment.
  - -- Carry out feasibility measurements and modeling.
  - -- Design, build, and test prototypes for use in full-scale demonstration.

- Radar Scope
  - -- Evaluate candidate designs for through-wall motion detection.
  - -- Carry out feasibility measurements and modeling.
  - -- Design, build, and test prototypes for use in full-scale demonstration.

	FY 2005	FY 2006	FY 2007
Surveillance and Threat Neutralization in Urban Environments	4.000	4.000	8.000

(U) This program will develop systems to demonstrate the detection and defeat of threats specific to conflict and stabilization operations in the urban environment. These threats include roadside bombs, car bombs, suicide bombers, snipers, rocket propelled grenades and mortars launched from inside urban boundaries. Detection technologies under development include intercept and localization of unintentional radiated emissions of remote-control circuits; multi-static radars for standoff identifications of shrapnel-packed bombs; detection of anomalies in vehicle dynamics;

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standoff identification and localization of explosive vapors/effluents; high fidelity 3D mapping performed from a high altitude (>15,000 feet) airborne platform; and multi-mode integrated acoustic and radar-based systems to backtrack to the source of fire. An additional technology thrust includes developing remotely powered sensors, which are passive and covert until probed with a single laser source. Neutralization technologies include targeted RF jamming of triggers; techniques to cause incomplete detonation of explosives; portable fast-erecting blast shields; and technologies to non-destructively and reversibly control urban access routes. These capabilities will be transitioned to Army and Special Operations ground forces to support urban operations planning with an initial focus on the targeting and intelligence components in FY 2008.

(U) Program Plans:
- Evaluate candidate technologies for wide-area/standoff and choke-point/portal-screening applications.
- Prove feasibility in lab on sub-scale tests.
- Design, build, and test prototype for choke-point applications and wide-area applications.

	FY 2005	FY 2006	FY 2007
Integrated Sensor Is Structure (ISIS)	11.000	18.000	0.000

(U) The ISIS program is developing a sensor of unprecedented proportions that is fully integrated into a stratospheric airship and that will address the nation’s need for persistent wide-area surveillance, tracking, and engagement for hundreds of time-critical air and ground targets in urban and rural environments. ISIS is achieving radical sensor improvements by melding the next-generation technologies for enormous lightweight antenna apertures and high-energy density components into a highly-integrated lightweight multi-purpose airship structure – completely erasing the distinction between payload and platform. The ISIS concept includes 99% on-station 24/7/365 availability for simultaneous AMTI (600km) and GMTI (300km) operation; 12-plus months of autonomous, unmanned flight; hundreds of wideband in-theater covert communications links; plus CONUS-based sensor analysis and operation. The ISIS technology is planned for transition to the Army's PEO-ASMD, Air Force Joint Warfighter Space and the Missile Defense Agency at the conclusion of Phase IV which is anticipated to be completed by FY 2011. Beginning in FY 2007, this program will reside in PE 0603287E, project SPC-01.

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(U) Program Plans:

- Developed objective system concept designs enabling simultaneous AMTI and GMTI operation, one year logistics-free operation, 99% on-station availability, and high-bandwidth covert communications.
- Identified specific mass-reducing technologies for key radar, power, and airship components.
- Develop, mature, and demonstrate lightweight technologies for system integration (i.e. high-energy density batteries, electronic circuits on thin-film barrier materials, advanced multi-purpose airship hulls, regenerative fuel technologies).
- Design and simulate new radar modes: tracking air and ground targets through the clutter notch; detection and response to rockets, artillery, and mortars (RAM); detection of dismounted enemy combatants; and “track-all-the-way” fire-control.
- Design, build and demonstrate a fully-operational scaled flight system demonstrating complete system integration over an extended period (~3 months).

	FY 2005	FY 2006	FY 2007
Nuclear Facilities and Materials Tracking Assessment (NUCTRAC)	0.000	5.000	9.000

(U) The goal of the Nuclear Facilities and Materials Tracking and Assessment (NUCTRAC) program is to develop new technologies and systems that advance and enhance DoD capabilities in the area of hostile nuclear activities. The short-term goal of this effort is to solicit designs for the detection of fissile and radioactive materials, weapons programs, intact weapons and potential precursors for production of nuclear Weapons of Mass Destruction (WMD). The long-term goal of this effort is to enable robust detection of covert nuclear programs, nuclear weapons or materials en route to the United States, protection of U.S. interests overseas, and improvement in monitoring and inspection regimes. Specific objectives of NUCTRAC are to apply technology advances in computing, information processing, data fusion, low cost manufacturing, telecommunications, nanotechnology, robotics, signature detection, remote interrogation, facility characterization, mobile sensors, autonomous radiation detection technology and other recent advances to the detection of fissile materials, nuclear weapons and programs.

(U) Program Plans:

- Solicit detector concepts and develop to a level usable in Phase II development.
- Develop NUCTRAC preliminary design, risk management plan, and technology and system maturation plan.

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– Develop sufficient system concept fidelity to validate program goals and objectives.

	FY 2005	FY 2006	FY 2007
Hostile Fire Indicator (HFI)	0.000	3.957	8.000

(U) The Hostile Fire Indicator (HFI) program will develop an airborne extension of the Boomerang Rapid Response program to provide rotorcraft with situational awareness of small arms fire. Currently, pilots may be unaware that they are receiving small arms fire until it impacts in the vicinity of the crew cabin or some other critical and monitored system. The HFI system was initially designed to detect and locate the source of any small arms projectiles passing within meters of aircraft with a high probability of detection and precise source-location accuracy. Based on the successes achieved thus far, the application of this program will be extended to the development of a portable system for use by the individual soldier. The HFI technology is planned for transition to USSOCOM by the end of FY 2010.

(U) Program Plans:

- Measure background noise on one U.S. Army and two SOF helicopters.
- Demonstrate downrange projectile detections at significant distances.
- Optimize signal processing for the operational on aircraft electromagnetic noise environment.
- Demonstrate cross-range bullet detection capability.
- Demonstrate projectile source location capability.
- Develop and demonstrate the performance of a man-portable HFI detection system.

	FY 2005	FY 2006	FY 2007
Speckle Exploitation for Enhanced Reconnaissance (SEER)	0.000	0.000	6.000

(U) The Speckle Exploitation for Enhanced Reconnaissance (SEER) program will develop a system to exploit the information carried in optical speckle. It will provide long-range non-cooperative identification of moving/stationary targets using the incoherent scattered laser speckle

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return of reflected active laser radiation. By ignoring optical phase, the system can be made much less complex with lower size, weight, power, and cost, and with reduced sensitivity to adverse turbulence-induced atmospheric distortion. Technical achievements under other programs in this PE/Project provide the basis for radically new approaches to measuring target characteristics under conditions that limit the performance of conventional sensors. Target characteristics potentially obtainable include target image, shape, size, detailed structural features, surface texture, reflectivity, polarization, macro and micro dynamics, and other advanced threat properties. By extending the operating range of current active electro-optic sensors, SEER enables the friendly platform to stand off from the maximum operating range of hostile sensors/weapons, while executing the targeting task and directing weapons against targets. Transition to the Army is expected to occur by FY 2010.

(U) Program Plans:
- Develop algorithms that reliably and uniquely associate target signatures with speckle patterns.
- Perform major system design trades.
- Implement algorithms using optical MEMs or other related technologies to achieve reduced size, weight and power.
- Design, develop, field, and test a prototype system on a tactical vehicle for transition to an operating command.

	FY 2005	FY 2006	FY 2007
Rescue Transponder	6.000	2.000	2.000

(U) Building upon technologies developed in other sensor programs, the Rescue Transponder (RT) program will investigate the use of covert localization and tracking technology to provide a very low probability of detection (LPD) call for help signal. The system is expected to use a wide band radio frequency signal with low power and extremely low duty cycle. The goals of the RT Program are to develop a small, rugged, transponder that provides a call for help to friendly forces. The RT system will operate over ranges that enable rescue forces or surveillance systems to receive its signals. It will support accurate localization by rescue forces, and permit transmission of identifying, authenticating, and status information. The Rescue Transponder technology is planned for transition to the Joint Personnel Recovery Agency in FY 2007.

(U) Program Plans:
- Conducted successful field tests using prototype bench equipment.

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- Completed initial tag miniaturization effort.
- Fabricated, tested, and validated performance levels of tags.
- Develop tags which enable the user to be identified and localized by airborne or advantaged receivers.
- Design a custom digital and microwave integrated circuit to allow miniaturization.
- Build and test prototype tags, devices and transmitters and author viable manufacturing plans.
- Demonstrate the military utility of RT to transition partner.
- Conduct field experiments demonstrating first generation miniaturized tags.

	FY 2005	FY 2006	FY 2007
Low-Cost Cruise Missile Defense (LCCMD)	8.500	6.450	0.000

(U) The LCCMD program will design, develop, demonstrate and transition an affordable electronically scanned array (ESA) 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 developed a novel active ESA concept using low cost single-chip transmit/receive module concept and is presently focused on the maturation and demonstrations. The LCCMD technology is planned for transition to the Army's Space and Missile Defense Command at the conclusion of Phase III, which is anticipated to be completed at the end of FY 2006.

(U) Program Plans:

- Built and tested active ESA antenna.
- Established Memorandum of Agreement transitioning active ESA to the U.S. Army partner for completing seeker integration, testing and performance analysis.
- Fabricated seeker back-end and integrated with ESA seeker antenna in preparation for ground or flight test.
- Conducted ground and flight testing.

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- Integrate seeker with U.S. Army demonstration interceptor.
- Conduct end-to-end system performance via captive carry flight testing.

	FY 2005	FY 2006	FY 2007
RF MEMS Improvement	6.977	0.550	0.000

(U) RF MEMS switches in the X, Ka, and Ku band hold great promise for DoD radar applications due to their inherent small size, light weight, low power consumption and low loss. The RF MEMS Improvement program will extend lifetimes, develop inexpensive packaging techniques, and enhance RF performance of RF MEMS switches to allow use in devices such as phase shifters, reconfigurable apertures, and tunable filters. The RFMIP program is anticipated to transition via industry to phased array antenna, reconfigurable communication front-end, seeker, and steerable aperture programs being developed by the Army, Navy, and Air Force.

(U) Program Plans:

- Developed process improvements, supported by predictive performance models, in competing MEMS fabrication and packaging techniques.
- Performed six design and testing iterations of packaged MEMS.
- Demonstrated ability to fabricate low-cost, low-loss, long life MEMS switches meeting DoD requirements.
- Demonstrated reliable accelerated lifetime tests for fast determination of switch reliability pursuant to further lowering the cost of such devices.
- Demonstrate fully integrated switch circuits (e.g., fully integrated phase shifters, switchable filters) with substantially better performance than discrete switch approaches.
- Demonstrate integration of RF MEMS switches together with integrated transistor circuits so as to realize compact, single-chip systems.

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	FY 2005	FY 2006	FY 2007
Digital Radio Frequency Tag (DRAFT)	1.375	0.000	0.000

(U) The Digital Radio Frequency Tag program developed 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 developed a small, lightweight and affordable RF Tag for data exfiltration from unattended ground sensors and for communication with vehicles and personnel throughout the battlespace. This is particularly useful for the identification and location of coalition units. Other advanced tag capabilities were investigated and developed, adding additional communications capabilities to the tags for enhanced interoperability with combat identification and communications systems. These added capabilities give the tags dual-mode capability: to function as a tag when radar is present, or to function as a more conventional radio beacon device when radar is not available. Additionally, small-scale tag variations have been considered for other missions, including dismount and non-cooperative red-target tracking, with the net effect of substantially enhancing situational awareness and combat identification advantages for U.S. forces in conventional and unconventional ground operations. The DRAFT program transitioned to the Army and to the Marines in FY 2005.

(U) Program Plans:

- Completed 5 baseline radar tag prototype units.
- Completed design of advanced tag concepts.
- Conducted laboratory device testing and characterization.
- Conducted airborne field tests and user demonstration.
- Completed dual-mode tag communicator design.
- Demonstrated dual-mode tag communicating on SATCOM waveform.
- Developed dismount/red tag prototypes and conduct laboratory device testing and characterization.

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	FY 2005	FY 2006	FY 2007
Wireless Vibration Sensor Initiative	1.000	0.000	0.000

(U) Continued support of the development and qualification of open system architecture wireless sensor technology.

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

- Not Applicable.

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COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Sensors and Exploitation Systems SEN-02	134.742	127.789	143.083	148.506	145.463	146.963	145.963

(U) Mission Description:

(U) The Sensors and Exploitation Systems project develops and demonstrates advanced sensor and exploitation technologies. These efforts, along with those in Project SEN-01 provide warriors with situational awareness and precision target identification. The project is driven by four needs: (1) countering camouflage, concealment and deception (CC&D) of mobile ground targets; (2) providing near-real-time, semi-automatic exploitation of wide-area moderate- and high-resolution imagery; (3) obtaining real-time, accurate battle damage assessment; and (4) accomplishing robust, precise identification, precision fire control tracking and engagement of high value targets. These needs are addressed by the following programs: Advanced Exploitation Systems Technology, Network Centric Sensing and Engagement, Advanced Optical Sensor Technology, and Advanced Radar Sensor Technology.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Advanced Exploitation Systems Technology	42.098	40.182	42.463

(U) The Advanced Exploitation Systems Technology program develops semiautomatic methods to interpret and exploit sensor data. The objective is to detect and identify military threats. Data sources include national, theater and, organic surveillance and reconnaissance systems. Critical performance issues are timeliness, accuracy, error rates, and interpretation workload. The program addresses the challenges of target acquisition and tracking under restrictive rules of engagement. The technology applies advanced signal processing and machine vision to leverage advances in sensor capabilities. Initiatives in this program include the following:

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- The Frequency-Diverse Spatial/Spectral Sensor Exploitation initiative develops methods to better utilize advanced sensors. The initiative encompasses high-resolution multispectral, multipolarization, radio frequency, and electro-optical and active optical sensors. The program significantly improves mapping, terrain characterization, target detection, and situational awareness. The technology explores applications for both medium-and high-altitude deployment and permits fusion, automated exploitation, and visualization of products from diverse classes of sensors. These sensors and processing techniques enable commanders to enjoy wide-area detection, characterization, and geolocation information along with application to facilities, vehicle, and dismounted targets in both tactical situation awareness and strategic indication and warning. These tools support rapid mapping and terrain characterization support in near-real time for support of robotic and manned maneuver forces. Technologies are planned for transition to the National Geospatial-Intelligence Agency.

- The National/Tactical Exploitation (NTEX) initiative develops technologies to locate and identify enemy air defense and missile units. NTEX uses multi-source imagery and data from both National reconnaissance systems and tactical sensor assets. Under a DARPA Memorandum of Agreement with the National Geospatial-Intelligence Agency (NGA), the project places researchers in facilities with access to real data and analysts. These researchers submit their sensor exploitation developments for rapid assessment by operational analysts using real world data. NTEX builds upon technologies developed under the DARPA Semi-Automated Imagery Intelligence (IMINT) Processor Advanced Concept Technology Demonstration. The program demonstrates increased capability to model, detect, and locate air defense targets and surface threats, including those that have been denied, modified, or have yet to be modeled. The NTEX technology is planned for transition to the National Geospatial-Intelligence Agency at the conclusion of Phase III anticipated to be completed by FY 2006.

- The Video Verification and Identification (VIVID) initiative develops technology to automate moving target strike operations for remotely piloted aircrafts (RPAs). Program products support both precision strike operations and military surveillance. VIVID enables the handoff of targets between wide area coverage Intelligence, Surveillance, and Reconnaissance systems and local video surveillance platforms. The technology provides techniques for precision target identification in video including fingerprinting techniques and related technology to permit reacquiring previously observed vehicles. The program also features techniques enabling video sensors to autonomously and simultaneously track multiple vehicular targets through dense traffic, temporary occlusion or exit from sensor field of view, in military surveillance and strike operations, and supports target detection of moving vehicles and/or dismounts in very low resolutions. VIVID technologies significantly advance the capabilities of video surveillance and moving target strike for numerous military missions, including military operations in foreign urban areas. DARPA has established a MOA with the Air Force to transition the VIVID

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technology to the Predator. The VIVID technology is planned for transition at the conclusion of Phase II which is anticipated to be completed by the end FY 2007.

- The Tactical Sensor Network Technologies (TSNT) initiative develops detection, tracking, identification, and pattern analysis capabilities that operate in all nodes (fixed or mobile) within a networked, distributed multi-sensor system. The processing to be performed at each network node depends on the sensors reporting to that node, the subscribing commanders, and resource management decisions. TSNT exploits locality of sensing, but will leverage the advantages of a self-forming adaptive network for signal processing. Algorithms are designed to be aware of the sensor network and adapt their processing algorithms based on self-discovered network topology. The algorithms also take into account power management constraints, communications bandwidth limitations, and constraints found in the local environment. TSNT is resilient to the failure of any node while maintaining sufficient consistency to support commanders' collaborative tactical planning. Technologies are planned to be transitioned to US Army (PEO IEWD).

- The Exploitation of 3-D Data (E3D) initiative develops techniques for rapidly exploiting 3-D sensor data. Such data is proliferating from growing numbers of advanced sensors, such as Laser Detection and Ranging (LADAR) and Laser Identification Detection and Ranging (LIDAR). Three dimensional data represents a rich resource for use in precision target identification. E3D demonstrates that the target identification performance of 3-D information greatly surpasses that of 2-D image-based methods. The program effort consists of three distinct processes: (1) Target Acquisition (TA) develops methods based on search of a local 3-D volume for detecting possible targets in scene; (2) Target Recognition (TR) investigates mathematical approaches to the identification of specific targets and target types detected by TA; and (3) Modeling explores methods of modeling the structure and variability into a representation exploitable by TR to identify targets. The resulting software tools are designed to be integrated into operational ground stations processing 3-D sensor data. The E3D technology is planned for transition to the SOCOM at the conclusion of Phase IV anticipated to be completed in FY 2006.

- The Dynamic Tactical Targeting (DTT) initiative develops sensor control and data fusion technologies to enable warfighters to manage a process to find, identify, track, target, and destroy mobile, time sensitive targets (TSTs). Current targeting technology is too slow to maintain target track and support prosecution of these fleeting targets. DTT is designing and demonstrating a system that: 1) leverages existing National/Theater Intelligence, Surveillance, and Reconnaissance (ISR) processes for timely extraction of critical data; 2) fuses organic sensor data with ISR data from all sources to enable multi-scale estimation of target location, identity, and activity; 3) dynamically tasks standoff, organic, and embedded sensors to fill ISR coverage gaps and provide relevant sensor observation in areas of tactical

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interest; and 4) processes and manages the voluminous data produced by various sensors in time to provide the warfighter information required to prosecute TSTs. The DTT technology is planned for transition to the Air Force by FY 2007.

- The All-Source Target Characterization initiative develops a collection and measurement capability to characterize new targets as they emerge on the battlefield. This effort develops tools to permit rapid user interaction with imagery, sensor data, and processing results and provides real-time feedback to operators indicating target key features and other discriminates. The technology provides tools to process and disseminate target signatures to the field in usable formats for direct insertion into operational systems and enhances operator interfaces with extant analysis workstations to allow on-the-fly collection of signature data with little/no intervention for the operator. Technologies are planned for transition to the Air Force Distributed Common Ground Station.

- The Automatic Target Recognition Technology (ATR) initiative matures automation of target detection and analysis for multi-view multi-sensor data. This will enable the efficient identification of targets of interest, to the level of fingerprinting of those targets according to their unique characteristics. This capability will enable analysts to track vehicular targets, even though the views are taken at relatively infrequent intervals. It will also enable analysts to make full use of both novel national and increasingly abundant tactical data sources, including EO/IR, SAR, and multispectral data. Using robust target cueing and identification methods gleaned from advanced academic pattern recognition and object recognition theory, the project will develop recognition capabilities over large target classes within a computational form factor appropriate for insertion into a distributed architecture of sensor platforms. This effort will develop tools to permit rapid user interaction with imagery and processing results and provide real time feedback to operators indicating target decision confidence. The project will operate in conjunction with the National Geospatial-Intelligence Agency (NGA), and includes transition of capabilities to the production environment at NGA.

(U) Program Plans:

– Frequency-Diverse Spatial/Spectral Sensor Exploitation
  - -- Design, analyze, and assess new concepts for exploitation of advanced sensors: RF, EO/IR and active optical frequency-agile spatial/spectral/polarimetric.
  - -- Perform phenomenological investigations to assess target signature stability, variability and separability.
  - -- Develop prototype tools for exploiting signatures.
  - -- Design, develop, and evaluate brassboard sensor hardware.

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-- Evaluate system performance under controlled environments.
-- Design, develop, and evaluate form, fit, and function sensor hardware.
-- Integrate on the aircraft and evaluate performance in flight test over realistic targets and large clutter sets.

– National/Tactical Exploitation (NTEX)
-- Demonstrate the ability to recognize components of specific air defense and missile units using automated processing of national/tactical sensor data.
-- Demonstrate the ability to model targets observed from sensor views, then locate and identify those targets autonomously in subsequent imagery.
-- Demonstrate the ability to model denied and expedient targets from a few sensor views, then locate instances of those targets that would be overlooked by analysts in a real-world situations.

– Video Verification and Identification (VIVID)
-- Develop techniques to automate detection, classification, and tracking of enemy, mobile, surface targets in visible and infrared motion imagery acquired by remotely piloted aircraft (RPA).
-- Develop automated techniques to detect moving vehicles and dismounts in single or multiple fixed areas for ISR operations or final inspection of weapon strike areas.
-- Demonstrate integrated, semi-automated engagement of hostile surface targets with precision weapons guided by data from video sensors on airborne platforms.

– Tactical Sensor Network Technologies (TNST)
-- Develop algorithms for distributed situation assessment at all nodes of a networked group of sensors.
-- Integrate and assess distributed system performance in large-scale simulation and limited-scale testing.
-- Demonstrate robustness of TSNT networked sensing under network and environmental stresses.
-- Incorporate tracking, target identification, and target assignment algorithms for fully distributed operation.

– Exploitation of 3-D Data (E3D)
-- Provide additional synthetic data and collect advanced laser radar (LADAR) data for research and development modules.

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-- Acquire and refine 3-D models of potential target vehicles.
-- Develop tools to locate, classify, identify, and characterize the operational states of ground targets using data from 3-D sensors (e.g., LADAR) making use of structural models of candidate target geometries.
-- Proliferate structural models to encompass hundreds of candidate target types.
-- Expand capabilities to perform precision recognition in the presence of articulation and obscuration.
-- Improve performance of real-time processing.
-- Integrate E3D software into a fingerprinting system capable of identifying specific vehicle instances.
-- Extend model-based vision technologies to classify, identify, and characterize the operational state of ground targets from other sources of 3-D sensor data.

– Dynamic Tactical Targeting (DTT)
-- Demonstrate human interaction with closed-loop control of fusion and sensor management in a simulation environment.
-- Develop rapid 4D registration of multiple tracks to enable continuous tracking of numerous targets.
-- Develop information fusion methods and the capability to plan and replan appropriate sensor platforms; enable continuous track of multiple time-sensitive targets simultaneously.
-- Develop end-to-end robust system capability with integrated DTT components in the Air Force Research Laboratory testbed.
-- Develop system measures of performance for evaluations.
-- Integrate the system with an existing Air/Ground Battlespace Simulator/Testbed and perform experiments.
-- Complete a robust laboratory demonstration of the system.
-- Build a system to test in field demonstrations.

– All-Source Target Characterization
-- Obtain a large set of target vehicles of extreme variety.
-- Characterize the shape, surface material, equipment, and mobility characteristics.
-- Obtain data on all vehicles in a scripted scenario representative of future threat operations.
-- Release data for a baseline set of vehicles to develop target models.
-- Conduct quarterly characterization exercises given a fixed time to develop a new set of target models from observed data.

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-- Evaluate performance by comparing reconstructions with the shape, surface material, equipment, and mobility characteristics measured on the actual vehicles.

– Automatic Target Recognition Technology (ATR)
  -- Develop problem sets from real data taken by tactical and national assets, and mature ATR algorithms to achieve 90% identification performance on realistic recognition problems.
  -- Mature registration technology to facilitate multi-source recognition.
  -- Develop algorithms to permit near real-time performance to enable ATR against larger and more generalized target sets to keep pace with data collection rates.
  -- Employ advanced pattern recognition methods to enable fingerprinting of specific kinds of vehicular targets using multiple stand-off data sources.

	FY 2005	FY 2006	FY 2007
Network Centric Sensing and Engagement	28.144	38.683	39.605

(U) The Network Centric Sensing and Engagement Program develops technology and tools to support precise situational awareness, rapid targeting, and precision engagement through the exploitation of systems of networked sensors. Network-centric sensing acknowledges a group of sensors as a system and leverages networked intercommunication to enable system performance superior to that of uncoordinated individual sensors. Applications include advanced target detection, acquisition, tracking, and combat identification. The technology is suited to ground - based fixed and mobile sensors and airborne multi-ship sensor systems. Exploiting the potential of network-centric sensing requires a number of approaches. Required technology advances include: sensor-to-sensor communications, multi-sensor management, sensor system georegistration, real-time data fusion, advanced tracking, and network-centric sensor operational modes. Initiatives in this program include the following:

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- The Camouflaged Long Endurance Nano-Sensors (CLENS) initiative develops low-cost, lightweight micro-sensors to detect, geolocate, track, and classify targets in difficult environments. The system leverages ultra-wideband radio technologies developed for advanced communications. The combination of active, coherent, distributed-network sensing offers unique capabilities not possible from stand-alone, single-point systems. CLENS enables reduced force protection and supports monitoring of borders and critical CONUS sites, and long-duration covert monitoring of target sites such as terrorist camps. CLENS has broad application in support of comprehensive intelligence, surveillance, and reconnaissance for situational awareness and enables persistent sensing of dismounted combatants in forested areas and other tough environments. The CLENS technology is planned for transition to the SOCOM at the conclusion of Phase III anticipated to be completed by FY 2007.

- The Tactical Targeting Network Technologies (TTNT) initiative develops rapidly reconfigurable, affordable, robust, interoperable, and evolvable communications technologies. Resulting technologies support airborne network-centric targeting. Goals for the TTNT tactical network are: (1) reconfigurability in fractions of a second; (2) wideband capacity (10+Mbit/s) on demand; (3) near zero (2 milliseconds) latency for high priority messages; (4) complete interoperability with Link 16; and (5) cost effectiveness. This program addresses technical issues including physical waveforms and frequency allocations, fast security subsystems, and distributed network management. It is developing novel digital processing techniques to eliminate the need for centralized network synchronization. TTNT is pursuing an omni-antenna-based approach with a self-adaptive, channel sensing, multiple user access protocol. It employs spread spectrum waveforms optimized for rapid carrier acquisition, featuring powerful turbo code error detection and correction. This physical layer provides well-integrated security architecture. The network architecture is designed to exploit commercial-off-the-shelf technology wherever possible. TTNT will incorporate Joint Tactical Radio System software defined radio standards. Performance in simulations and laboratory testing with bread-board equipment exceeds the current phase program goals. TTNT is designing and fabricating a full security architecture brass-board system. TTNT transition activities include developing Software Communications Architecture (SCA) compliant software, advanced power amplifier, wideband transceiver, and Low Probability of Intercept/Low Probability of Detection (LPI/LPD) modes so that TTNT is moderately low risk for incorporation into production programs. The TTNT technology is planned to transition to the Air Force, Army, Marine Corps, and Navy, and is anticipated to be completed in FY 2006.

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- The Quint Networking Technology (QNT) (formerly Rotorcraft SIGINT/COMINT Geolocation) is a modular, multi-band, network data link program focused on providing capabilities that close the seams between five nodes - aircraft, unmanned combat air vehicles (UCAV), weapons, tactical unmanned air vehicles (UAV's) and air control ground units. The program designs, develops, evaluates and demonstrates robust, affordable data link technologies suitable for use by weapons, tactical UAV's, and air control units. This includes shrinking the package size of data link capabilities from the current 1000 in^3 to 10 in^3, the size of a cell phone. These data links enable precision strike and efficient machine-to-machine targeting against time critical and mobile targets, support combat identification of targets, disseminate tactical UAV and ground sensor data, and provide bomb impact assessment (BIA). The data links allow secure weapon handoff from the launch platform to any of several control platforms in the combat area, both air and surface. The QNT units provide two modes: a low rate bi-directional mode and a high data rate mode capable of either continuous or a burst imagery/video transmission. Dynamic net resource management technology will scale to support hundreds of vehicles in flight. Advanced information security techniques provide secure weapon data links and controller handovers. QNT technology transitions via insertion into DoD's existing and emerging weapons, tactical UAV's, and tactical handheld units after the program is completed in FY 2008.

- The Federated Object-level Exploitation (FOX) initiative assembles the results of image analyzers, target recognizers, and signal processors into a collection (federation) of situation estimates and describes objects of interest ranging from terrain, roads, and surface type to militarily significant vehicles, buildings, and people. The estimates enable prediction of future observables, enabling differences between the predictions and the observations to trigger change detection and analysis that updates the estimates. The estimates are maintained, in a consistent manner at multiple sites, distinguished by different areas of interest, target sets, and data sources. Technologies are evaluated on real-world data at experimental facilities collocated with operational analysts, and transition takes place incrementally as individual technologies mature. FOX began in FY 2006 and transitions to Network-Centric Warfare Technology, PE 0603766E, Project NET-01 in FY 2007.

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- The Persistent Operational Surface Surveillance and Engagement (POSSE) program creates a system of systems framework in which a mix of surveillance assets, both operational and developmental can be coordinated and exploited to yield persistent surveillance of insurgent activities. The program focus is on the Iraqi theatre, using a spiral approach designed to insert enhanced counter-insurgency capabilities into operational use as soon as possible, followed by improvements and enhancements as they become integrated through a domestic testbed. The efficacy and timeliness of surveillance afforded by the program's systems-level approach will significantly exceed that afforded by individual ISR components, and will result in substantially enhanced force protection for fixed sites, convoys, and military operations. The framework includes data exploitation at both forward-deployed and national sites to support both quick-reaction cuing to engage insurgents, and deeper forensic analysis to identify their support structures. The POSSE program is jointly funded with the Joint Improvised Explosive Device Defeat Task Force. POSSE technologies are planned for transition to the U.S. Army Intelligence and Security Command.

- The Target Geolocation from a UAV (GeoLoc) program uses novel photogrammetric techniques to provide accurate geolocation of ground targets (<10 meters CEP) from small and mid-size UAVs. This represents an order of magnitude improvement in accuracy compared to instrumentation used on high-end UAVs. Further it requires no new hardware on-board the aircraft and does not rely upon prepared reference imagery. This photogrammetric technology will permit UAVs to not only observe targets for the first time, but also to direct fire from coordinate-seeking weapons. Furthermore, the technology will be extended to provide real-time geolocation on moving vehicles as well, enabling engagement of moving targets without use of laser designators, and without any human operators in harms way. The thrusts and future capabilities of the GeoLock Program are: detection, precision identification, tracking, and destruction of elusive surface targets from networked manned and unmanned systems. Technologies are planned for transition to the U.S. Air Force.

- The Wide Area Video Exploitation project will develop technology to enable wide field-of-view visible and infrared imagery (EO/IR) framing cameras in airborne platforms to detect and track, in real time, multiple moving objects under a wide range of conditions and topography. Current systems are able to collect data and provide an ability to backtrack individual targets post-facto. The Sonoma-Plus project aims to provide a real-time ability to track in forward time multiple potential targets from high-altitude video imagery. On-board processing will be crucial since imagery data volumes will amount to gigabytes per second. Multi-hypothesis tracking of dozens and eventually hundreds of entities will also be developed, and imagery stabilization based on prior digital elevation models will also facilitate tracking and track analysis. Technologies are planned for transition to the U.S. Army.

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(U) Program Plans:

– Camouflaged Long Endurance Nano-Sensors (CLENS)
  -- Develop a breadboard ultra-wide band radar micro-sensor for dismount detection and tracking.
  -- Design receiver nodes to process micro-sensor that detects into tracks and exfiltrates data.
  -- Develop tracking algorithms to consolidate range-only detects into contact tracks.
  -- Fabricate targeted form factor micro-sensors.
  -- Conduct ground demo with one receiver/processor and many micro-sensors.

– Tactical Targeting Network Technologies (TTNT)
  -- Complete brassboard design and fabrication.
  -- Complete brassboard TTNT flight experiments and demonstrations at large scale.

– Quint Networking Technology (QNT) (formerly Rotorcraft SIGINT/COMINT Geolocation)
  -- Conduct analysis, design and hardware-in-the-loop tests.
  -- Build and evaluate brassboard in stage 1 tests.
  -- Cycle and test brassboard Stage 2 tests and flight tests.

– Federated Object-level Exploitation (FOX)
  -- Acquired real-time access to data from all-source national and tactical sensors operating over an area of interest.
  -- Established connectivity at three testbed sites which the data was received.

– Persistent Operational Surface Surveillance and Engagement (POSSE)
  -- Conduct a comprehensive analysis of existing surveillance assets in the Iraqi theatre.
  -- Develop a systems architecture and asset utilization plan that maximizes persistent surveillance capability in high priority regions, based on currently available assets.
  -- Identify coverage and gaps and required new capability needed to satisfy persistent surveillance and force protection objectives.
  -- Define a spiral development plan that emplaces initial capability in theatre as early as possible, and identifies needed enhancements and new capabilities to be inserted in subsequent phases.

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-- Initiate accelerated development of gap-filler sensors and/or platforms.
-- Develop an integrated capability to exploit all theatre-deployed ISR assets in a coordinated, systematic manner.
-- Test an initial POSSE exploitation system at the National Training Center.

– Target Geolocation from a UAV (GeoLoc)
-- Evaluate platform noise models.
-- Demonstrate reliable point feature extraction.
-- Integrate with UAV telemetry.
-- Demonstrate real-time geolocation from airborne video.
-- Integrate and transition to Common Ground Station.
-- Extend algorithms for geolocation of moving targets.
-- Demonstrate real-time geolocation of moving targets.

– Wide Area Video Exploitation
-- Evaluate imagery and algorithms to perform stabilization and multi-hypothesis tracking.
-- Build video processing architecture to demonstrate an ability to track 50 or more moving entities in playback mode of 50 Megapixel video data with a frame rate of at least 1 Hz.
-- Integrate computer architecture with a collection platform to provide tracking over hundreds of entities simultaneously in 100 Megapixel (or higher) video data.

	FY 2005	FY 2006	FY 2007
Advanced Optical Sensor Technology	26.519	27.869	42.015

(U) The Advanced Optical Sensor Technology Program significantly improves warfighter situation awareness, surveillance, reconnaissance and targeting. The program exploits advancements in electro-optic, hyper spectral imaging, optical polarimetry, and advanced three dimensional active optic sensing. Initiatives in this program include the following:

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- Standoff Precision ID in 3-D (SPI 3-D) is developing an affordable sensor package capable of high-resolution 3-D images for confirmatory target ID at long ranges (>10km). The SPI-3D sensor overcomes obscuration and penetrates foliage, camouflage, and cloud layers via range gating. The system provides intensity, range and polarization for each pixel in the field of view with each laser pulse – SPI-3D is the first laser radar with this capability. The program includes a series of ground and air vehicle demonstrations of SPI-3D precision ID capabilities and track fusion techniques. The objectives are to provide: (1) rapid acquisition; (2) polarization exploitation; (3) intensity mapping; and (4) high range resolution. Results will provide commanders with significantly improved identification of enemy ground targets, both stationary and moving. The SPI-3D sensor system employs existing commercial-off-the-shelf optics, focal plane arrays and gimbals, combined with a novel Pockels cell range measurement technique. The SPI-3D technology is planned for transition to the Air Force at the conclusion of Phase III, which is anticipated to be completed by FY 2008.

- The Synthetic Aperture Ladar for Tactical Imaging (SALTI) initiative will develop and demonstrate an airborne synthetic advanced laser radar (ladar) imager capable of producing high-resolution three-dimensional imagery at long ranges. The SALTI approach combines the long-range day/night access afforded by conventional synthetic aperture radar (SAR) with the interpretability of high-resolution optical imagery and the exploitability of three-dimensional (3-D) imagery, for fit and deployment within a tactical-sized package. The technical objective of the SALTI program is to provide a proof-of-concept for operation at tactically relevant high altitudes and at long ground ranges. Development and demonstration of long range performance is scheduled to be conducted through FY 2008. The SALTI technology is planned for transition to the Air Force by 2009.

- The Video Exploitation for Precision Identification initiative explores new ways to overcome or circumvent the limitations of automatic recognition of targets (ATR) and monitoring fixed sites and facilities by exploiting the unique opportunities provided by persistent sensing, such as high temporal and spatial sampling rates, long-term observation, and perspective diversity. The project develops techniques specifically designed for exploitation of persistent and ubiquitous sensing over larger and larger areas of interest. The project includes basic research that addresses a broader and more robust view of target recognition, classification, and generalization. The thrusts and future capabilities of the PEPS Program are: detection, precision identification, tracking, and destruction of elusive surface targets. The capabilities will serve as a force multiplier for urban area operations. Technologies are planned for transition to the Air Force.

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- The Firesight Aerial Sensor Mapper (FSAM) program will develop an autonomous UAV-based sensor exploitation and decision support capability that provides dynamic situational awareness for large-scale firefights in urban environments. The FSAM concept will combine novel thermal and acoustic gunfire detection capabilities with a 4D (space-time) fusion approach within the framework of a probabilistic inferencing network to reliably locate and map the array of urban firing events with low spatial uncertainty and with low rate false alarms. This includes the distribution of shooters and weapon types as well as the firepower movements and trends associated with the dynamically changing battlefield situation. FSAM will enhance lethality and survivability of the friendly ground forces by dramatically increasing the speed, accuracy and completeness of detecting, identifying, tracking and destroying the elusive enemy in complex urban terrain, including the irregular combatants. Integrated with and within the emerging battle command systems, intel systems and unmanned/manned networks, FSAM will be a force multiplier in urban area operations. FSAM will be the first system to address battalion-level urban firefight detection and tracking, providing field commanders with a holistic, up-to-the-minute dynamic picture of the movements, evolution, and emerging firepower tactics of the enemy unit in the complicated urban battlespace. Further, the real-time picture provided by FSAM will not be a collection of pixels, but interpreted, computer-understandable formal descriptions of the evolving events and entities on the battlefield. As such, FSAM's output will be a critical automated input to battle command and intelligence systems. Technologies are planned for transition to the U.S. Army (PM RUS).

- The High Precision Long Range Laser Designator/Locator (HPLD) program seeks to develop an affordable laser target designator/locator package that allows the user to observe, track, and designate a target at operationally significant ranges. The focus of this effort is to develop new target-in-the-loop active optics approaches and novel high accuracy pointing methods to enable a single operator to precisely determine the GPS coordinates of a target that is multiple kilometers away. Once precisely determined, the operator will be able to observe, track, and laser designate the target as required, using a single device. This device will be used by ground combat elements and small unmanned aerial vehicles that conduct terminal attack control and call for fire and will be designed to support their full range of deployment methods. It will also survive in a harsh environment for long periods of time with minimal maintenance. The High Precision Long Range Designator/Locator technology is planned for transition to the Army and SOCOM by FY 2009.

- The Omni-Directional Flash & Launch Detection, Positioning, Classification and Observation System (MEGA) program will develop a low-cost, omni-directional staring, infrared sensor, which will provide circumpheral imagery of its surroundings. The MEGA sensor and algorithms will be used to detect weapon discharges in its field of regard, locate and classify them and, using appropriate communication means, convey the information to other units or systems connected to it.

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- The Advanced Optical Sensing (AOS) program will develop the next generation of airborne optical surveillance systems while also developing and demonstrating the ability to obtain very high dynamic range, high resolution hyper-spectral and polarimetric information from airborne imagers. The program will focus on bringing recent advances in photonic and other technologies to military airborne optical sensing systems. This effort will develop advanced digital signal processing to support onboard image reconstruction, atmospheric correction and system calibration. Techniques will be explored to realize a 1 meter class aperture wide-field-of-view imaging system within less than half a meter of thickness. Adaptive optics techniques, such as those used for atmospheric correction, will be explored to help combine sub-apertures while relieving alignment requirements. While electronic beam steering and zoom optics have been demonstrated with deformable mirrors and liquid crystal spatial light modulators, this program will seek to extend these technologies and make them practical for airborne surveillance systems.

- The Large Area Coverage Search-while-Track and Engage (LACOSTE) program enables persistent tactical-grade Ground Moving Target Indication (GMTI) in dense urban areas. Wide-area continuous tracking of moving vehicles requires very small coverage gaps, small resolution cells, and target separation and identification features. The ideal sensor has the area coverage rates of GMTI radar and the resolution/identification capabilities of an electroptical infrared system. The LACOSTE program will provide wide area surveillance, simultaneous tracking, and target engagement with optical and infrared sensors for tactical GMTI operations. The program is developing a sensor with a very wide field of regard (90° cone angle), and a wide instantaneous field-of-view (FOV) that is rapidly scanned in a search-while-track mode – tracking up to 10,000 targets in an urban area. Additionally, the LACOSTE sensor will provide precision tracking to enable engagement on a large number (~100) targets within that same field of regard with a minimal penalty on the search-mode area coverage rate. The program is also developing a rapid "zoom" capability for target identification enables feature-aided tracking through dense target environments plus sufficient target identification for separating like-targets when back-tracking a particular target via the historical track data. The LACOSTE technology is planned for transition to the Air Force at the conclusion the program anticipated in FY 2009.

- The SandBlaster program will develop a passive pilot enhancement system that fuses visible, IR and millimeter wave radiation to enable multiple helicopters to land safely in conditions of severe brown- and white-out. SandBlaster will exploit the low attenuation property of dust (fog and snow) on millimeter wave radiation. A passive millimeter wave system will be developed to preclude detection and prevent interference as would be expected from multiple active systems operated in close proximity. Four fundamental piloting situational awareness enablers will be addressed: (1) pilot's ability to "see" in limited visibility conditions, (2) pilot's awareness of helicopter drift,

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(3) pilot's awareness of slope of terrain, and (4) display technology matched to mission and human factors considerations. The technology developed under this program will transition to USSOCOM and the Marine Corps in FY 2008.

- The Super-Resolution Vision System (SRVS) initiative will develop and build a field prototype soldier-portable optical system that will demonstrate improved recognition and identification range over existing systems. The key technical innovation is exploitation of an atmospheric turbulence-generated micro-lensing phenomena to generate better than diffraction-limited images. SRVS will facilitate new operational and tactical opportunities for land forces. Through enhanced resolution imaging SRVS will (1) extend target recognition and identification to decisively longer distances; (2) overcome atmospheric turbulence, which now limits the ability of high-resolution optics; and (3) increase target identification confidence to reduce fratricide and/or collateral damage. It will develop advanced technologies to enable atmospheric, turbulence-induced, super resolution, and will culminate in a field demonstration of a prototype. Technology developed under this program will transition to the Services in 2010.

(U) Program Plans:

– Standoff Precision ID in 3-D (SPI-3D)
  - -- Developed and tested brassboard of complete imaging system, including laser and Pockels cell elements.
  - -- Determined accuracy and precision of ranging technique.
  - -- Conducted long range ground tests from mountaintop test site.
  - -- Developed flight engineered system and conducted preliminary test flights.
  - -- Integrate and demonstrate system from manned aircraft against stationary and moving targets.
  - -- Conduct series of confirmatory tests to demonstrate utility of the SPI-3D sensor system under a wide range of environments and target conditions.
  - -- Transition SPI-3D sensor technologies and system concept to Services.

– Synthetic Aperture Ladar for Tactical Imaging (SALTI)
  - -- Complete sensor packaging and ground testing.
  - -- Refine image formation processing algorithms to coherently combine multiple laser pulse returns and to compensate for platform motion during the collection of these multiple pulses.

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-- Complete Early Flight Tests, which will produce the first-ever Synthetic Aperture Ladar high-resolution 2D and 3D image images from aircraft.
-- Characterize coherent infrared propagation through the atmosphere under operational conditions, to assess the feasibility of long range operation.
-- Develop lasers for higher power and higher bandwidths to support Long Range Demonstration (LRD).
-- Demonstrate, in LRD, SALTI performance at operationally significant ranges on contractor-owned airborne testbed.

– Video Exploitation for Precision Identification
-- Instrument an overseas military facility with a dense set of still and video sensors.
-- Regularly insert instrumented vehicles and soldiers into the ambient traffic and activities.
-- Select a broad set of relevant technologies and implement as software prototypes.
-- Evaluate prototypes based on their ability to reconstruct aspects of the instrumented vehicles and soldiers.
-- Select prototypes for integration into a real-time testbed.
-- Design, build, and operate a video exploitation testbed, providing regular feedback to technology developers.
-- Transition technologies to relevant acquisition programs for target identification, site characterization, and force protection.

– Firesight Aerial Sensor Mapper (FSAM)
-- Develop and demonstrate the feasibility of detecting multiple simultaneous shooters (AK-47, mortars, RPG) in obstructed urban terrain using video IR imaging and processing combined with urban-capable acoustic sensor data operating in conditions comparable to UAV-based sensors, at Yuma Proving Grounds.
-- Develop and demonstrate fusion algorithms capable of integrating the acoustic and video IR sensor data with 3D urban terrain information and prior-time information into a time-dependent 3D map of individual and aggregated red force actions.
-- Design and evaluate a brassboard FSAM integrated hardware/software system.
-- Design and evaluate a form-fit and function FSAM hardware system for UAV installation and conduct end-to-end system performance tests that include all aircraft effects under static and dynamic conditions.
-- Conduct airborne flight-testing and demonstrate performance with the fully integrated FSAM / UAV / Battle Command system.
-- Perform user evaluations in order to develop the system CONOPS and to demonstrate FSAM's capabilities to the warfighter community.

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– High Precision Long Range Designator/Locator (HPLD)
  -- Build and demonstrate target-in-the-loop adaptive optics ability to achieve high resolution laser pointing and imaging of small targets.
  -- Validate the pointing accuracy of eye safe integrated optics at targets multiple kilometers away.
  -- Design, build, and demonstrate an integrated HPLD system of low weight and volume that validates the ability to be deployed and erected by dismounted troops.

– Omni-Directional Flash & Launch Detection, Positioning, Classification and Observation System (MEGA)
  -- Develop and demonstrate IR sensor prototype.
  -- Develop and demonstrate stationary omni system.
  -- Develop and demonstrate mobile platform omni system.
  -- Integrate mobile system with vehicle and demonstrate in series of field tests.

– Advance Optical Sensing
  -- Investigate approaches for producing large aperture imaging systems with constrained size.
  -- Explore uses of adaptive optics to provide optical corrections for multiple sub-apertures.
  -- Investigate technologies for optical beam steering and optical zoom that can be applied to airborne optical systems.
  -- Develop advanced signal processing techniques for the rapid formation of optical imagery.
  -- Design, build and demonstrate next generation airborne surveillance system.
  -- Incorporate state-of-the-art automatic target recognition capabilities into system.
  -- Transition system to services for production and fielding.

– Large Area Coverage Search-while-Track and Engage (LACOSTE)
  -- Develop objective system concepts enabling wide-area stand-off sensor for urban tactical-grade Ground Moving Target Indication (GMTI) tracking.
  -- Develop electroptical infrared electronically scanned sensor components.
  -- Develop optical GMTI tracking algorithms.
  -- Lab test the sensor parameters against measured urban data.

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-- Manufacture and integrate the LACOSTE sensor components.
-- Rooftop demonstration of large cone-angle electronically scanned urban GMTI.

– SandBlaster
  -- Test attenuation properties of dust on passive millimeter wave imaging and develop system requirements.
  -- Develop and identify the millimeter wave camera and related situational awareness technologies.
  -- Integrate the system and demonstrate capabilities.

– Super-Resolution Vision System (SRVS)
  -- Investigate optimal control algorithms and implementation using optical MEMs and chip-based technologies.
  -- Perform system design.
  -- Design and develop a brassboard prototype for laboratory and field experimentation and developmental testing.
  -- Integration into a prototype soldier-portable optical system.

	FY 2005	FY 2006	FY 2007
Advanced Radar Sensor Technology	32.081	21.055	19.000

(U) The Advanced Radar Sensor Technology program promises significant improvements in military sensor performance in situation awareness, surveillance, reconnaissance and targeting applications. Its emphasis is on surface targets and threats. Program efforts are focused on exploiting emergent and novel radar sensing technology and phenomenology. Key elements are advancements in ultra-wide band, bistatics, UHF/VHF, polarimetric change detection, tomographic imaging, space-time adaptive processing and other advanced signal processing, advanced Ground Moving Target Indication (GMTI) techniques, and foliage, building-penetrating, and ground-penetrating radar phenomenology. Program developments are integrated with current and emerging military platforms. Emphasis is on the most stressing military radar sensor challenges. Examples are operations featuring complex cluttered ground environments; those against small and slow moving surface targets; urban operations, and situations where camouflage, decoys and countermeasures must be overcome. Initiatives in this program include the following:

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- The Wide Area All Terrain Change Indication and Tomography (WATCH-IT) initiative developed real-time VHF/UHF synthetic aperture radar (SAR) automatic change detection and target discrimination technologies. WATCH-IT provides the commander with rapid, robust detection of threat systems in the open, under camouflage, and in foliage. The program features discrimination algorithms that examine change detections to determine if they have threat vehicle characteristics. Indications of change cue on- or off-board high-resolution sensors to perform target identification. WATCH-IT is designed to operate from platforms, such as high altitude unmanned air vehicles (UAVs). The technology will demonstrate high area-coverage rates with few false alarms. WATCH-IT provides commanders with a critical capability that currently does not exist. The program also developed techniques to extract 3-D vehicle images from multiple-pass polarimetric SAR imagery. This capability enables rejection of confusers (i.e., decoys, relocated vehicles that are not of military significance), thus greatly improves target classification/identification. DARPA established an MOA with the National Geospatial – Intelligence Agency for this program in September 2004. The WATCH-IT technology transitioned to the NGA at the conclusion of Phase II in 2005.

- The Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER) initiative radically altered the fundamental “front-end” signal processing architectures of advanced military sensors. It accomplished this through the real-time integration of a dynamic environmental knowledge database. Real-time “environmental awareness,” absent in conventional systems, dramatically improves clutter and interference rejection and significantly enhances sensor products. Current radio frequency sensors with adaptive signal processing estimate the background interference using sample statistical estimation. Key technologies included advanced algorithms and high-performance computing architectures capable of memory-intensive adaptive signal processing. The KASSPER technology transitioned to the Air Force during FY 2005.

- The Augmented Aerial Sentry (AAS) program will develop a rapidly-deployable airborne system to provide assured protection of permanent or temporary U.S. base camps in hostile territory. AAS will include ground-based, wide area sensors in conjunction with air platforms to maintain continuous surveillance of the area around the camp, detecting potential intruders or weapon launches. The suite of airborne sensor platforms can be tasked locally to investigate potential threats; lock on to personnel or weapons involved in an attack; allow commanders to confirm threats; or authorize precision weapons to engage them.

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- The goal of the Bipedal Detection project is to develop technology for the detection of humans walking (or running) using Ground Moving Target Indication (GMTI) radar hosted aboard a moving platform. Design criteria for the optimal radar system and operations concepts will be developed as part of the signal processing algorithm development. Multiple platforms will be required for system performance to show general bipedal motion detection over wide areas. Challenges include detection of motion below the minimum discernable velocity of the radar system, and discernment of multiple moving objects within a single beam width. Technologies are planned for transition to the US Army.

- The Generation After Next Airborne Surveillance Radar (GAN) initiative evaluated new concepts for wide area coverage airborne ground surveillance radar technology by exploiting wide-beam staring systems rather than narrow-beam scanning systems. The approach studied challenges associated with low revisit rates, limited concurrency of modes, low power efficiency, low resolution, and sensor management.

- The Tethered Ultra-Long baseline Sparse Aperture (TULSA) initiative studied developing new means of exploiting single-ship airborne long-baseline sparse apertures. The initiative investigated techniques for deploying, calibrating, powering, feeding and processing received signals from active end bodies deployed on long, towed tethers, and signal processing to support use of single-aircraft, towed long-baseline sparse arrays for: (1) emitter geolocation and (2) long baseline multi-static radar applications, such as GMTI multi-lateration.

- The Networked Detection and Ranging (NetDAR) initiative is addressing an impending bandwidth crisis in radar. Commercial pressures on bandwidth usage will make it difficult for military radar systems to operate in peace time without interfering with or being interfered by other transmission sources. This initiative will explore technologies to turn this bandwidth crisis into an asset. By using signals of opportunity across the spectrum, systems will be developed that can passively exploit a multi-static and only transmit to augment the RF propagation environment. Multi-Input Multi-Output (MIMO) radar concepts will be developed that coherently integrate multiple signals to efficiently use the entire RF spectrum. This now makes all RF sources assets instead of interference sources. This will include adaptive waveform diversity and extending MIMO radar into airborne sources as a revolutionary approach to conventional multi-static radar. This program has evolved into the Visibuilding program in PE 0603767E, Project SEN-01.

(U) Program Plans:

– Wide Area All Terrain Change Indication and Tomography (WATCH-IT)

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Sensor Technology PE 0603767E, Project SEN-02

-- Collected data using low-frequency, high-resolution polarimetric SARs.
-- Quantified the robustness of wide area change detection to factors, such as aircraft heading, depression angle, database aging, topography and terrain cover.
-- Assessed alternative change detection algorithms to determine the robustness to data variations, the computational requirements, and other factors impacting suitability for implementing WATCH-IT on an UAV.
-- Quantified the probability of detection and false alarm rate for a range of operating conditions.
-- Investigated methods to generate synthetic target signatures using software models or scaled frequency measurements.
-- Demonstrated WATCH-IT using the Foliage Penetration (FOPEN) SAR Advance Technology Development (ATD) system.
-- Demonstrated real-time, on-board change detection and high-speed discrimination processing in the ground station.

– Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER)
-- Developed advanced expert-reasoning algorithms using real and simulated data sets in non-real-time (offline) and real-time modes.
-- Developed real-time, high-dimensionality KASSPER software.
-- Conducted off-line KASSPER Constant False Alarm Rate & Radar (CFAR) demonstration.
-- Defined high performance embedded computing architecture to enable rapid memory access; design, build, test, and demonstrate.
-- Demonstrated KASSPER performance gains in real-time processing environment using real data sets.

– Augmented Aerial Sentry
-- Develop system architecture that will utilize existing and newly-developed sensing technologies to track potential and imminent threats.
-- Demonstrate effectiveness of system architecture.
-- Develop, demonstrate, and test system that incorporates multiple sensing technologies to provide situational awareness to commanders.

– Bipedal Detection
-- Conduct laboratory and airborne data collections using Ground Moving Target Indication (GMTI) radars and ground-level movements of dismount soldiers.

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- -- Develop algorithms to extract and classify human walking, running, and other repetitive activities based on collected data.
- -- Develop design concepts and perform a review of the algorithms, radars, and system concept for detection, tracking, and disambiguation of multiple humans performing repetitive bipedal activities.
- -- Field a prototype system and demonstrate an ability to monitor a wide area and detect and track up to a hundred dismounts simultaneously.

– Generation After Next Airborne Surveillance Radar (GAN)
- -- Developed missions and concepts of operation to evaluate GAN sensor concepts.
- -- Outlined basic functional requirements to support proposed missions and concepts of operation.
- -- Developed strawman concepts for GAN and evaluated their ability to satisfy the specified functional requirements.
- -- Developed a roadmap outlining an objective GAN system and an investment strategy.

– Tethered Ultra-Long baseline Sparse Aperture (TULSA)
- -- Developed a multi-sensor localization concept.
- -- Developed and evaluated relative navigation concepts to achieve desired geolocation accuracy.

– Networked Detection and Ranging (NetDAR)
- -- Develop hybrid passive/active radar system concept.
- -- Quantify performance benefits of multi-input multi-output exploitation of full RF spectrum.
- -- Design, build, test, and demonstrate multi-sensor integration experiment.
- -- Demonstrate performance gains in real-time.

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	FY 2005	FY 2006	FY 2007
360 Degree Portable Surveillance and ReConn Unit	2.400	0.000	0.000

(U) The 360 Degree Portable Surveillance and ReConn Unit project designed and fabricated an extremely large format video camera suitable for airborne reconnaissance by military forces in Iraq and elsewhere. The goal was to produce a 400-megapixel video camera – the world's largest. With suitable optics, such a camera will support the tracking of individual vehicles throughout a 10-km x 10-km area, or to enable moving target detection in a similar sized area.

(U) Program Plans:
- Created 48 M-pixel MegaSkyCam from modular components (digital focal panes, GPS and data links).
- Integrated eight MegaSkyCams to create the end device.
- Demonstrated detection and tracking algorithms on an array of processors to produce automated alerts.

	FY 2005	FY 2006	FY 2007
Sandia Intelligent Systems & Robotics Center	3.500	0.000	0.000

(U) Selected and funded research projects at the Sandia Intelligent Systems & Robotics Center.

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

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development				R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E			
COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	111.145	101.797	157.367	159.094	155.760	151.097	151.597
Guidance Technology GT-01	39.002	51.973	68.005	69.399	60.707	60.500	60.000
Classified GT-CLS	72.143	49.824	89.362	89.695	95.053	90.597	91.597

(U) Mission Description:

(U) The Guidance Technology program element is budgeted in the Advanced Technology Development Budget Activity because it is developing system oriented technologies that will improve our ability to navigate weapon systems with more precision and increase the capability to meet current and emerging threats.

(U) The Guidance Technology project will increase the ability of Global Positioning System (GPS) users to operate effectively in the presence of enemy jamming; to increase the versatility of navigation systems applications by developing microelectromechanical sensor inertial navigation system technologies; and to apply the geolocation technologies/techniques to precision threat geolocation of short-dwell emitters or passive air defense systems. 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 project.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E

(U) **Program Change Summary:** *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	114.330	103.272	111.473
Current Budget	111.145	101.797	157.367
Total Adjustments	-3.185	-1.475	45.894
Congressional program reductions	-0.097	-1.475	
Congressional increases	0.000		
Reprogrammings	0.000		
SBIR/STTR transfer	-3.088		

(U) **Change Summary Explanation:**

FY 2005	Decrease reflects DOE transfer for P.L. 108-447 and SBIR/STTR transfer.
FY 2006	Decrease reflects undistributed reductions for Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Increase reflects increased emphasis on classified projects, extension of MEDUSA through brassboard testing, and expansion of the Robust Surface and Subsurface Navigation Thrust.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2006
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, Project GT-01

COST (In Millions)	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Guidance Technology GT-01	39.002	51.973	68.005	69.399	60.707	60.500	60.000

(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. Thrusts are included in this project to improve our ability to navigate when the Global Positioning System (GPS) is jammed or otherwise unavailable; to increase the versatility of navigation systems applications by developing microelectromechanical sensor inertial navigation system technologies; and to apply the geolocation technologies/techniques to precision threat geolocation of short-dwell emitters or passive air defense systems.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
MEDUSA	21.002	18.000	13.005

(U) The Multifunction Electro-Optics for Defense of U.S. Aircraft (MEDUSA) program will develop the technologies and systems to give the U.S. air dominance at low altitude and at night. This program will develop the technologies to leap-frog reactive end-game countermeasures and enable increased threat warning times, denial of launch, and put EO-IR air defense threats at risk. MEDUSA is a three-part technology program: (1) conduct phenomenological measurements and develop countermeasures and target classification/identification techniques; (2) develop critical component technologies such as high power IR laser sources, advanced IR detectors, and fibers for high power IR transmission; and (3) develop and demonstrate an end-to-end MEDUSA system. The MEDUSA technology is planned for transition to the Air Force and Army at the conclusion of technology development and flight demonstration, which is anticipated to be completed during FY 2011.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, Project GT-01

(U) Program Plans:

- Developed and evaluated MEDUSA countermeasure and classification techniques and conduct phenomenological measurements.
- Fabricated and evaluated initial critical component technologies.
- Continued refinement of MEDUSA system designs.
- Built and demonstrated, from a tower, the breadboard MEDUSA design concept against realistic targets and environments.
- Fabricate and evaluate full-scale focal plan arrays and supporting technologies to support flight domain objectives.
- Build and flight test a MEDUSA brassboard design against realistic targets and environments.

	FY 2005	FY 2006	FY 2007
Advanced Gyroscopes	4.500	4.973	4.000

(U) The Advanced Gyroscopes program is investigating the feasibility of a very high-accuracy gyroscopes and other technologies to provide extremely precise navigation, with a goal of reducing noise error to 10^{-5} degree/hour or less. This would enable more robust operations in several applications—from underwater (including covert submarine operation and littoral navigation around obstacles) to outer space (from space flight to precise, autonomous satellite positioning). Technical challenges include the exploitation of quantum effects, such as correlated photons and atom interference effects, as well as gravity and gradiometer based technologies.

(U) Program Plans:

- Developed concepts for achieving the required accuracy.
- Continue to evaluate feasibility of underlying approach via analysis and laboratory measurements.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, Project GT-01

	FY 2005	FY 2006	FY 2007
Precision Inertial Navigation Systems	8.500	8.000	9.800

(U) The Precision Inertial Navigation Systems program will develop an entirely new class of inertial navigation instruments using atomic inertial force sensors. These sensors utilize the quantum-mechanical wave-like nature of atoms in the atomic analogue of an optical interferometer to provide unprecedented sensitivity to accelerations and rotations. The atomic sensors will further be used to measure the local gravitational field gradient to ensure that instrument alignment is properly maintained throughout vehicle maneuver, thus mitigating gravity-induced navigation errors. Initial program efforts will focus on developing fundamental technology components upon which later systems would be constructed. The PINS technology is planned for transition to the Navy and Air Force at the conclusion of Phase 3, which is anticipated to be completed by FY 2008.

(U) Program Plans:

- Develop and demonstrate an inertial navigation system with positional bias drift rate below 5 meters/hour.
- Develop compact narrow-linewidth, tunable 780 nm laser sources with large modulation bandwidth via monolithic solid-state microchip design.
- Demonstrate motion-compensated gravity gradiometer.
- Demonstrate approaches for GPS free navigation combining MEMS inertial navigation with locally derived location position information.

	FY 2005	FY 2006	FY 2007
Robust Surface and Sub-Surface Navigation (RSN/SSN)	5.000	11.500	18.000

(U) The Robust Surface and Sub-Surface Navigation (RSN/SSN) program, formerly known as Navigation via Signals of Opportunity (NAVSOPP), will provide the U.S. Warfighter with the ability to navigate effectively when the Global Positioning System (GPS) is unavailable due to hostile action (e.g. jamming) or blockage by structures and foliage. The RSN/SSN program will use signals of opportunity and specialized

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signals from a variety of ground-, air-, and space-based sources; these will be received on the Warfighter's forth coming software defined radios, and will use specially tailored algorithms to determine position. Other signals such as the Earth's magnetic field (micro deviations), cyclic variations in the Earth's gravitational field due to tidal motion, and judiciously placed low frequency RF beacons will also be used. The greater strength and diversity of these signals will provide coverage when GPS is denied due to lack of penetration into buildings and underground, and when severe multipath is a problem. This is a two part program: (1) cataloging and assessing of potential exploitable signals followed by analysis and performance modeling and hardware-based concept validation and (2) designing, testing, and demonstrating of a (non-form-fit) of a prototype receiver(s) and algorithms for geolocation using the signals of opportunity. The RSN/SSN technology is planned for transition to United States Special Operations Command and the Air Force at the conclusion of Phase 3, and is anticipated to be completed by FY 2008.

(U) Program Plans:
- Evaluate feasibility of candidate approaches using modeling, analysis, and simulation.
- Develop critical RSN/SSN technologies and conduct phenomenological measurements to validate the down-selected concepts.
- Design, fabricate and test functional prototype systems for above-ground and underground use.
- Field test and demonstrate the functional prototype in realistic environments.
- Perform technical risk mitigation experiments and analysis on the bimorph based magnetic sensors, the piezo-electric driving motors and signal and control processing algorithms.
- Integrate technologies into a micro sensor and radiometer structure.

	FY 2005	FY 2006	FY 2007
Navigation-Grade MEMS Inertial Measurement Unit (IMU)	0.000	9.500	15.500

(U) The Navigation-Grade MEMS Inertial Measurement (IMU) program will develop micro-scale accelerometers and gyros with navigation-grade performance that use only milli-watts of power. The program will transcend traditional single mass-spring methods for navigation sensing and will explore alternative approaches, such as multiple, interconnected mass-spring systems, micro-levitated spinning structures, micro-optical readout mechanisms, atomic interferometric readout mechanisms, and fluidic contortions.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, Project GT-01

(U) Program Plans:
- Attain 3D resonator structures (e.g., spheres, full wine-glass structures).
- Develop levitation methods.
- Develop fluid contortion sensing.
- Develop micro-environmental control.
- Control electronics integration.

	FY 2005	FY 2006	FY 2007
Active Electrol-Optical Mapping and Navigation System (AONS)	0.000	0.000	7.700

(U) The Active Electrol-Optical Mapping and Navigation System (AONS) program will provide GPS-denied navigation and detailed building interior mapping to soldiers operating in urban environments. AONS will employ electro-optic system strengths in image registration and precision range to track and map a soldier's position continuously. Using image-flow methods, a compact, power-efficient camera and laser radar system will track the imagery from frame-to-frame and back out camera pose and position information to provide the soldier a very precise estimate of current position as well as a continuously upgraded map of the building or underground facility (UGF) being traversed. This same system will make real-time estimates of range and relative position of objects in the scene, and will provide real-time position estimates outside under GPS-denied conditions in urban, mountainous and even foliated areas given access to a high-resolution terrain map of the area. This system would match small-scale features, such as shrubs, trees and small buildings, to features in the map and provide real-time estimates of the soldiers location within that map. The capability will be transitioned to Army via PEO Soldier and USSOCOM starting in FY 2009.

(U) The primary technical challenges are the development of compact, integrated high-resolution passive EO/IR and multi-pixel or scanning laser radar systems along with the development of real-time processing capability to provide the soldier up to date position estimates both inside building and outside buildings in GPS denied conditions.

(U) Program Plans:
- Develop initial real-time navigation algorithms based on real and synthetic data.

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- Develop an integrated breadboard system with key initial sub-systems including video, laser radar and inertial navigation aids.
- Develop and demonstrate an integrated portable prototype AONS system.
- Demonstrate real-time navigation and building extraction.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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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

COST (In Millions)	FY 2005	FY2006	FY2007	FY 2008	FY 2009	FY 2010	FY 2011
Total Program Element (PE) Cost	48.582	48.765	50.951	50.291	51.345	52.421	53.481
Management Headquarters (R&D) MH-01	48.582	48.765	50.951	50.291	51.345	52.421	53.481

(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 security, travel, supplies and equipment, communications, printing and reproduction.

(U) Program Accomplishments/Planned Programs:

	FY 2005	FY 2006	FY 2007
Management Headquarters	48.582	48.765	50.951

(U) Program Plans:

- DARPA will continue to fund civilian direct-hires, both career and Section 1101 employees, and administrative support costs. Anticipated pay raise requirements are also funded. Full compensation for all 40 Section 1101 hires is reflected, including bonus packages.
- Security-related costs, to continue access controls, uniformed guards, and building security upgrades, are funded.
- CFO act compliance costs are funded.

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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) **Program Change Summary:** *(In Millions)*	**FY 2005**	**FY 2006**	**FY 2007**
Previous President's Budget	46.264	49.472	48.778
Current Budget	48.582	48.765	50.951
Total Adjustments	2.318	-0.707	2.173
Congressional program reductions	0.000	-0.707	
Congressional increases	0.000		
Reprogrammings	2.354		
SBIR/STTR transfer	-0.036		

(U) Change Summary Explanation:

FY 2005	Increase reflects a below threshold reprogramming to cover an increase to the salary budget and to accommodate the audit of financial statements.
FY 2006	Decrease reflects undistributed reductions of Section 8125 and the 1% reduction for Section 3801: Government-wide rescission.
FY 2007	Increase reflects costs budgeted for the audit of financial statements and financial feeder systems.

(U) Other Program Funding Summary Cost:

- Not Applicable.