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Department of Defense Fiscal Year (FY) 2006/FY 2007 Budget Estimates

February 2005



Research, Development, Test, and Evaluation, Defense-Wide

Volume 1

Defense Advanced Research Projects Agency (DARPA)

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**DEPARTMENT OF DEFENSE
FY 2006/FY 2007 Budget Estimates**

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DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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Defense Adv Research Projects Agcy
FY 2006 RDT&E PROGRAM

EXHIBIT R-1

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

Date: FEB 2005

| Line No | Program Element Number | Item | Act | Thousands of Dollars | | | S E C |
|------------|------------------------------|--|-----|----------------------|------------------|------------------|-------------|
| | | | | FY 2004 | FY 2005 | FY 2006 | |
| 1 | 0601101E | Defense Research Sciences | 01 | 130,223 | 169,571 | 130,090 | U |
| | | Basic Research | | 130,223 | 169,571 | 130,090 | |
| 10 | 0602301E | Computing Systems and Communications Technology | 02 | 316,590 | | | U |
| 11 | 0602302E | Embedded Software and Pervasive Computing | 02 | 19,824 | | | U |
| 12 | 0602303E | Information & Communications Technology | 02 | | 187,767 | 198,831 | U |
| 13 | 0602304E | Cognitive Computing Systems | 02 | | 149,782 | 200,799 | U |
| 14 | 0602383E | Biological Warfare Defense | 02 | 141,921 | 159,567 | 145,354 | U |
| 16 | 0602702E | Tactical Technology | 02 | 247,405 | 327,825 | 361,562 | U |
| 17 | 0602712E | Materials and Electronics Technology | 02 | 465,450 | | | U |
| 18 | 0602715E | Materials and Biological Technology | 02 | | 256,480 | 294,188 | U |
| 20 | 0602716E | Electronics Technology | 02 | | 261,406 | 241,736 | U |
| | | Applied Research | | 1,191,190 | 1,342,827 | 1,442,470 | |
| 31 | 0603285E | Advanced Aerospace Systems | 03 | 304,741 | | | U |
| 32 | 0603286E | Advanced Aerospace Systems | 03 | | 71,420 | 75,866 | U |
| 33 | 0603287E | Space Programs and Technology | 03 | | 222,880 | 223,811 | U |
| 43 | 0603739E | Advanced Electronics Technologies | 03 | 185,917 | 222,777 | 214,378 | U |
| 46 | 0603760E | Command, Control and Communications Systems | 03 | 189,062 | 219,765 | 216,408 | U |
| 47 | 0603762E | Sensor and Guidance Technology | 03 | 309,637 | | | U |
| 48 | 0603763E | Marine Technology | 03 | 13,051 | | | U |
| 49 | 0603764E | Land Warfare Technology | 03 | 80,961 | 62,546 | 139,100 | U |
| 50 | 0603765E | Classified DARPA Programs | 03 | 211,192 | 180,802 | 162,534 | U |

Defense Adv Research Projects Agcy
FY 2006 RDT&E PROGRAM

EXHIBIT R-1

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

Date: FEB 2005

| Line No | Program Element Number | Item | Act | Thousands of Dollars | | | S E C |
|---|--|------------------------------------|-----|----------------------|------------------|------------------|-------------|
| | | | | <u>FY 2004</u> | <u>FY 2005</u> | <u>FY 2006</u> | |
| 51 | 0603766E | Network-Centric Warfare Technology | 03 | 82,185 | 121,613 | 136,899 | U |
| 52 | 0603767E | Sensor Technology | 03 | | 201,917 | 189,452 | U |
| 53 | 0603768E | Guidance Technology | 03 | | 114,330 | 103,272 | U |
| | Advanced Technology Development (ATD) | | | 1,376,746 | 1,418,050 | 1,461,720 | |
| 134 | 0605502E | Small Business Innovative Research | 06 | 71,353 | | | U |
| 143 | 0605898E | Management HQ - R&D | 06 | 45,925 | 46,264 | 49,472 | U |
| | RDT&E Management Support | | | 117,278 | 46,264 | 49,472 | |
| Total Defense Adv Research Projects Agcy | | | | 2,815,437 | 2,976,712 | 3,083,752 | |

Program: *Basic
Research*

Agency: *Department of Defense--Military*

Bureau: *Research, Development, Test, and Evaluation*

Rating: *Effective*

Program Type: *Research and Development*

Last Assessed: *2 years ago*

| Key Performance Measures from Latest PART | Year | Target | Actual |
|--|-------------|---------------|---------------|
| Annual Measure: Certification in biennial reviews by technically competent independent reviewers that the supported work, as a portfolio, is of high quality, serves to advance the national security and is efficiently managed and carried out. | 2003&later | 100% | 100% |
| | | | |
| | | | |
| | | | |
| Annual Measure: Long-term Measure: Portion of funded research that is chosen on the basis of merit review Reduce non-merit-reviewed and -determined projects by one half in two years (from 6.0% to 3.0%) | 2005 | -50% | |
| | | | |
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| | | | |

Recommended Follow-up Actions

Status

Continue to emphasize the use of independent review panels in assessing the performance of the program.

Completed

Work 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.

Action taken, but not completed

Update on Follow-up Actions:

Program Funding Level (in millions of dollars)

| 2004 Actual | 2005 Estimate | 2006 Estimate |
|--------------------|----------------------|----------------------|
| 1,358 | 1,513 | 1,319 |

Program: DoD Applied Research Program

Agency: Department of Defense--Military

Bureau:



Rating: Moderately Effective

Program Type: Research and Development

Program Summary:

The Department of Defense's Applied Research program supports systematic, scientific study to gain understanding necessary to determine how the Department's military mission can be accomplished more effectively or more efficiently. Applied research often takes the results of basic research investments and carries them forward to determine the operational parameters of potential technologies and evaluate the practicality of applying those technologies to military needs.

The assessment of the Applied Research program found that:

- The program purpose and design are clear. The Department has built methodical processes for setting program goals and for reviewing progress. The program is designed to ensure that warfighters have superior and affordable technology to support their missions and to provide revolutionary war-winning capabilities.
- Reviews of the program by external review panels are not independent of program officials.
- 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.

In response to these findings, the Administration will:

1. Continue to ensure that adequate funding exists to carry promising basic research results into the realm of applied research.
2. Change the expert evaluation process to use fully independent review panels in assessing the performance of the program.
3. Work 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.

Key Performance Measures from Latest PART

| | Year | Target | Actual |
|---|------|----------|--------|
| Long-term Efficiency Measure: Reduce by half within three years, grant and contract award funding not (1) resulting from needs identified by military or technical experts within the Services or Agencies and (2) awarded through the merit-review process. Currently about \$1.0 B/yr. | 2006 | <\$800 M | |
| | 2007 | <\$500 M | |
| | 2008 | <\$500 M | |
| | | | |
| Annual Measure: Percentage of ambitiously chosen Defense Technology Objectives (DTO) targets achieved. | 2005 | 70% | |
| | 2006 | 70% | |
| | 2007 | 70% | |
| | 2008 | 70% | |
| Annual Measure: Portion of external technology area review panels that are fully independent (all external reviewers). | 2006 | 100% | |
| | 2007 | 100% | |
| | 2008 | 100% | |
| | | | |

Program Funding Level (in millions of dollars)

| <u>2004 Actual</u> | <u>2005 Estimate</u> | <u>2006 Estimate</u> |
|--------------------|----------------------|----------------------|
| 4,350 | 4,850 | 4,139 |

Program: *DoD Small Business Innovation
Research/Technology*

Agency: *Department of Defense--Military*

Bureau: *Research & Development*

Rating: *Results Not Demonstrated*

Program Type: *Research and Development*

Last Assessed: *1 year ago*

| Key Performance Measures from Latest PART | Year | Target | Actual |
|--|-------------|---------------|---------------|
| Long-term Measure: Revise the Commercialization Achievement Index (CAI) to eliminate counting of investments as commercialization no later than three years after receiving the first Phase II support. After that, count competitive sales receipts only. | 2004 | All | |
| | | | |
| | | | |
| Long-term Measure: Stop funding companies with more than 5 current or past Phase II awards in the last 5 years if the company is in the bottom quartile in the CAI. | 2005 | All | |
| | | | |
| | | | |
| Long-term Efficiency Measure: Emphasize commercialization so overall competitively awarded sales to the government (direct or indirect) from resulting products is at least equal to new R&D investment (Phases I-III), as a portfolio of prior 3-8 year investments (rolling average). | 2005 | TBD | |
| | 2006 | TBD | |
| | 2007 | TBD | |
| | 2008 | TBD | |

| Recommended Follow-up Actions | Status |
|---|-----------------|
| Change the way companies' past performance is assessed to ensure that it more closely matches the intent of the law. | No action taken |
| Look for ways to budget explicitly for the program's administrative costs. | No action taken |
| Seek to get highly successful awardees to enter the mainstream of Defense contracting. | No action taken |
| Tighten eligibility requirements for accepting proposals from companies and individuals that repeatedly fail to sell resulting products in the marketplace. | No action taken |

Update on Follow-up Actions:

The Department of Defense's program management is working with the Military Services and Defense Agencies to determine how to make the changes noted above. The Department is expected to reach agreement on how to implement the changes by the end of 2005.

Program Funding Level (in millions of dollars)

| 2004 Actual | 2005 Estimate | 2006 Estimate |
|--------------------|----------------------|----------------------|
| 1,100 | 1,133 | 1,500 |

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

(U) Mission Description:

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

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

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

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research | R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, R-1 # 1 | |

(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 biomolecular materials, interfaces and microsystems; materials and measurements for molecular-scale electronics and spin-dependent materials and devices.

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

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

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Applied Research | R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, R-1 # 1 | |

(U) **Change Summary Explanation:**

FY 2004 Decrease reflects SBIR/STTR transfer.

FY 2005 Increase reflects ten congressional adds in the areas of nanotechnology, photonics and electronics offset by a congressional reduction to the Biointerfaces program and undistributed reductions.

FY 2006 - 2007 Decrease reflects reduced emphasis on Simulation of Bio-Molecular Microsystems (SIMBIOSYS) and maturation of Bio/Info/Micro efforts into 6.2.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research | | | | R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Bio/Info/Micro Sciences BLS-01 | 40.602 | 57.779 | 52.389 | 52.180 | 56.794 | 60.925 | 64.925 | 64.925 |

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

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

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

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

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

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

(U) Program Plans:

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

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research | R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01 | |

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

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

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

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(U) Program Plans:

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

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

(U) The Bio Interfaces program will support scientific study and experimentation, emphasizing the interfaces between biology and the physical and mathematical/computer sciences. This unique interaction will develop new mathematical and experimental tools for understanding biology in a way that will allow its application to a myriad of DoD problems. Chief among them is the ability to seamlessly integrate and control mechanical devices and sensors within a biological environment – a critical aspect in the successful implementation of a major prosthetics effort.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research | R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01 | |

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

(U) Program Plans:

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

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

(U) The Biological Adaptation, Assembly and Manufacturing program will examine the structure, function, and informational basis underlying biological system adaptation, particularly to harsh environments, and the factors employed by the organism to assemble and manufacture complex biological subsystems. The unique stability afforded biological systems in their ability to adapt to wide extremes of physical and endurance (e.g., heat, cold, and sleeplessness) parameters will be examined and exploited in order to engineer stability into biological systems of Defense needs (such as blood or other therapeutics). In addition, the fault tolerance present in biological systems will be exploited in order to

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

(U) Program Plans:

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

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

(U) The Nanostructure in Biology program will investigate the nanostructure properties of biological materials to better understand their behavior and accelerate their exploitation for Defense applications. This new information about biomolecules will provide important new leads for the development of threat countermeasures, biomolecular sensors and motors, and molecular interventions to maintain human performance in the battlefield. This program will also develop approaches to mathematically predict a priori the structure of biological materials, especially

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proteins, based on the desired performance. This will enable the rapid design of new biosensors against previously unknown threats and the design of advanced catalysts based on biological activity to produce new materials of interest to DoD (e.g., tailored explosives). In addition, research will be conducted in the interaction, at the nanoscale, of biotic and abiotic materials and functions, a critical aspect in the development of advanced prosthetics. Finally, this thrust supported the early, basic work in biomagnetics, which has now been transferred to PE 0602715E, Project MBT-02.

(U) Program Plans:

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

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

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

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

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

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

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

- Not Applicable.

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

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

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

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

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

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

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

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

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

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Electronic Sciences ES-01 | 27.854 | 33.965 | 23.783 | 23.453 | 25.169 | 25.679 | 26.752 | 26.752 |

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

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

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

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

(U) Program Plans:

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

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

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

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

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

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

- (U) Program Plans:
- Model and simulate advanced structures for four classes of applications.
 - Improve modeling capability for predicting macro functionality from nanostructure.
 - Emphasize chemical synthesis.
 - Address parameters such as thermal stability, environmental chemistry tolerance (O₂, H₂O, etc) and photochemistry.

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

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

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

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

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

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

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

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

(U) Develop novel lithographic devices and new processes.

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

- Not Applicable.

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

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

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

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

(U) Program Plans:

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

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

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

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

(U) Program Plans:

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

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

(U) The major emphasis of this thrust is to provide the theoretical and experimental underpinnings of a new class of semiconductor electronics based on spin degree of freedom of the electron, in addition to (or in place of) the charge. Not only will this class of electronics lead to novel and faster electronic devices, but it will also serve as one of the key technology enablers for quantum communications and quantum computation.

(U) Program Plans:

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

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

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

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

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

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

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

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

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

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

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

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

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research | | R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project MS-01 | |

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

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

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

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

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

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

- Not Applicable.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | | | R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, R-1 # 12 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 0.000 | 187.767 | 198.831 | 213.723 | 245.838 | 245.670 | 235.670 | 230.670 |
| Intelligent Systems & Software IT-01 | 0.000 | 16.550 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| High Performance and Global Scale Systems IT-02 | 0.000 | 60.130 | 70.143 | 75.000 | 100.000 | 100.000 | 100.000 | 100.000 |
| Information Assurance and Survivability IT-03 | 0.000 | 53.698 | 62.944 | 69.036 | 70.617 | 70.077 | 70.077 | 70.077 |
| Language Translation IT-04 | 0.000 | 57.389 | 65.744 | 69.687 | 75.221 | 75.593 | 65.593 | 60.593 |

(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. This program element and the four projects included within it were created in accordance with congressional intent in the FY 2005 DoD appropriations bill with prior year funding budgeted in PE 0602301E, Projects ST-11, ST-19, ST-24, and ST-29.

(U) The Intelligent Systems and Software project develops 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 develops 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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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, R-1 # 12 | |

(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)

| | <u>FY 2005</u> | <u>FY2006</u> | <u>FY2007</u> |
|-----------------------------|----------------|---------------|---------------|
| Previous President's Budget | 191.456 | 226.016 | 248.989 |
| Current Budget | 187.767 | 198.831 | 213.723 |
| Total Adjustments | -3.689 | -27.185 | -35.266 |

Please note that this program element has been newly created from projects previously funded in PE 0602301E. The *Previous President's Budget* amount reflects projects ST-11, ST-19, ST-24, and ST-29 funded under that PE.

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| Congressional program reductions | -4.889 |
| Congressional increases | 1.200 |
| Reprogrammings | 0.000 |
| SBIR/STTR transfer | 0.000 |

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, R-1 # 12 | |

(U) **Summary Explanation:**

FY 2005 Decrease reflects congressional undistributed reductions offset by a congressional add for Secure Group Communications.

FY 2006 – 2007 Decrease reflects the termination of Project IT-01 in FY 2006 as programs transfer to the Network Centric Enabling Technology project (TT-13) in PE 0602702E. This decrease is offset by an increase in the Language Translation project (IT-04) where the next generations of speech and text translation devices are budgeted.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | | | R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, Project IT-01 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Intelligent Systems and Software IT-01 | 0.000 | 16.550 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

(U) Mission Description:

(U) This project develops new technology for software creation, processing, and database management to significantly improve software for systems that produce, store, and analyze information about battlespace operations. The software generates 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 information exchange as situations and resources modify over time. First, the design of complex Command, Control, Communications and Computation Intelligence, Surveillance, and Reconnaissance (C⁴ISR) systems are accelerated by formalizing descriptions of semantics, performance, and resource levels and developing design tools to use those formalisms to assemble systems. Second, the software enables field integration of legacy systems by providing general purpose tools that use these formalisms to search, browse, display, and combine services available to a command center, especially in coalition environments. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602301E, Project ST-11 and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|------------------------------------|---------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| DARPA Agent Markup Language (DAML) | (8.916) | 10.545 | 0.000 | 0.000 |

(U) The DARPA Agent Markup Language (DAML) program will develop military software tools for use on Intelink and other emerging Command and Control Link systems. The focus of the program is to develop technologies that enhance interoperability and extend the reach of the World Wide Web to programs, sensors, and other data sources. Moreover, the program will enable agent-based programs to share information through those mechanisms. DAML will develop a software language linking the information of a web resource to machine-readable semantics (ontology) which describes both data contents and service providers. This effort will provide new technologies for the intelligent integration of information across a wide variety of heterogeneous military sources and systems in real time. In addition, DAML is developing and evaluating a

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set of tools to transform existing intelligence and command/control software and enables the operation in network-centric computing environments, through the use of DAML ontologies and service descriptions. Without these automated tools, the cost of bringing older software systems into network-centric computing environments can be prohibitive. DAML tools help correlate application-specific ontologies to shared database schema, construct translators from application data structures to database schema, and build mediators that convert product streams from publishers to subscribers.

(U) Program Plans:

- Perform experimental analysis on and deploy Intelink DAML Briefing and Search Tools on an operational Intelink node.
- Demonstrate and prototype DAML tools for web applications for the Military and National Intelligence Community.
- Prototype suite of additional tools to encapsulate legacy software to support DAML ontologies, logics, and service descriptions.
- Conduct experimental analysis of DAML applications.
- Build example mediators to convert data among DAML ontologies, referencing external knowledge bases.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Automatic Target Recognition Technology | (4.502) | 5.000 | 0.000 | 0.000 |

(U) The Automatic Target Recognition Technology (ATRT) program will develop new sensor exploitation aids to detect targets in high volume sensor data with minimal human support. This program will support very large sets of targets (thousands of target types) with high identification performance and very low false alarm rates, as well as develop modeling methods to account for target variability, caused by partial damage, design difference, or equipment loaded onto the exterior of the vehicle. The program will support interaction with humans to supply operational context, guide hypothesis development, and adapt models. By developing techniques for in-the-field training of models, signatures, and scoring parameters, ATRT will identify vehicle-specific signatures and develop new target fingerprinting techniques. Finally, new methods to assist humans in achieving precise identification of ad hoc, poorly defined targets will be developed. The program supports rapid and accurate detection, recognition, and identification of targets in high volume sensor imagery. The imagery will enable a dramatic reduction in sensor-to-shooter timelines, supporting dynamic target engagement. Follow-on efforts are being pursued in PE 0603767E, Project SEN-02.

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- (U) Program Plans:
- Obtain a regular supply of data from field and developmental sensors, covering numerous target types in many environmental settings.
 - Estimate ground truth for those data to provide a foundation for periodic performance assessments.
 - Extend existing performance analyses to provide bounds on detection, identification, and fingerprinting performance for thousands of vehicle types.
 - Develop model generation, model update, detection, recognition, identification, and fingerprinting algorithms based on a range of technical approaches.
 - Periodically assess technologies on the field data, computing statistically significant estimates of performance to compare against the analyses.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Rapid Software Composition for Embedded Systems | (2.477) | 1.005 | 0.000 | 0.000 |

(U) The Rapid Software Composition for Embedded Systems program develops technology to permit rapid assembly of heterogeneous C⁴ISR components for execution on complex, highly parallel, real-time embedded architectures. The technology will explore techniques to permit rapid parallel code development and optimization and to leverage advanced architectures for development, exploration, and rapid deployment of C⁴ISR components. This program will provide tools and software libraries that allow C⁴ISR systems to be rapidly assembled from discrete, pretested components. In addition, developers will be assisted in assembling and tailoring C⁴ISR systems for mission-specific tasks. Furthermore, the technology will facilitate mapping C⁴ISR system components onto advanced run-time architectures for high performance operations in limited footprint environments (airborne, tactical vehicle, afloat). The tools created will optimize new C⁴ISR capabilities using spiral development processes without loss of performance.

- (U) Program Plans:
- Identify a set of challenge applications across the spectrum of C⁴ISR missions.
 - Assemble a library of kernel algorithm components.
 - Map the kernel components onto representative hardware architectures.
 - Develop input/output/state descriptions of each kernel component, as mapped to each architecture.
 - Construct tools to assemble kernel components into systems, including data flows and process/processor assignments.
 - Build predictive models of systems assembled from kernel components.

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- Verify run-time feasibility and achievement of required performance.
- Validate the tools and models within the challenge applications.

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

- Not Applicable.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | | | R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, Project IT-02 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| High Performance and Global Scale Systems IT-02 | 0.000 | 60.130 | 70.143 | 75.000 | 100.000 | 100.000 | 100.000 | 100.000 |

(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. The project comprises two primary components – Responsive Computing Architectures and Network Embedded Technology. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602301E, Project ST-19 and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|------------------------------------|----------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Responsive Computing Architectures | (78.351) | 60.130 | 70.143 | 75.000 |

(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 energy/power management, quality of service, algorithm/application computing diversity and scalable computing efficiency. The technologies 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 comprises Power Aware Computing and Communications, and High Productivity Computing Systems.

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

(U) The High Productivity Computing Systems (HPCS) program will provide DoD with significant technology and capability advancements for the national security and industrial communities by filling a critical gap between today's late 1980's 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 and development, and (3) full-scale development. HPCS will address a number of critical technology barriers over the next decade: (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 high-end computing application requirements, metrics and performance prediction tools will be used throughout the program to assess both technical and schedule progress.

(U) Program Plans:

- Power Aware Computing and Communications.
 - Provided a beta release of the PAC/C energy-aware simulator and modeling framework for the PAC/C subscale developers to evaluate.
 - Develop the final subscale demonstration projects.
 - Execute the final PAC/C demonstrations.

- High Productivity Computing Systems.
 - 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.

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- 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 comprising of processors, memory, interconnects, software, and programming environments that will result in high productivity computing systems.
- Perform critical technology assessment and full-scale engineering readiness review of the Phase II HPCS petascale systems and their viability for implementation in the 2010 timeframe.
- Perform down-select from the Phase II R&D participants based on their readiness for full scale development (Phase III), their ability to address the government's HPC needs in the 2010-2011 timeframe, and their commercial viability.
- Implement basic and applied software research in the revitalization of high-end computing.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|----------|---------|---------|---------|
| Network Embedded Technology | (20.010) | 0.000 | 0.000 | 0.000 |

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

(U) The program has developed technology to support faster and more reliable development of tactical software – that is, distributed real-time and embedded software for tactical applications, and in particular for the time-critical targeting domain. This technology is enabling programmers to safely and productively integrate so-called "cross-cutting" aspects, such as concurrency, synchronization, security, and memory management, with core functionality that implements the interaction of tactical software with the diverse and evolving suite of sensors and actuators that constitute the sensor-to-decision maker-to-shooter chain. The reusable code-base, tools and reference applications delivered by the program more effectively exploit human effort to produce high-quality software that has the adaptability, robustness, and efficiency required by time-critical targeting systems.

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(U) Program Plans:

- Developed scalable techniques for validation of tactical embedded software by computerized analysis of models of the system.
- Developed language representation and compilation techniques for fine-grained and coarse-grained; aspect-oriented programming of tactical embedded systems.
- Developed a mechanism whereby quality-controlling functionality can be packaged in a portable and reusable form, and that is suitable for automated integration by the analysis and composition tools.
- Developed model-driven tools and representations for generating military system software that supports *flexible binding*, meaning that the allocation of resources to software functions may take place at any time after system design, up to and including during deployed system operation.
- Developed quality-of-service enabled services for persistence, fault tolerance, and high-bandwidth sensor data transmission, such as those services that are required by the highly dynamic nature of modern air-to-ground warfare.
- Developed catalogs of patterns and pattern languages that formalize the successful techniques associated with developing tactical embedded systems middleware and applications.

(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, Project IT-03 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Information Assurance and Survivability IT-03 | 0.000 | 53.698 | 62.944 | 69.036 | 70.617 | 70.077 | 70.077 | 70.077 |

(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 by the Command and Control Information Systems (Project CCC-01, PE 0603760E), Information Integration Systems (Project CCC-02, PE 0603760E), Joint Warfare System (Project NET-01, PE 0603764E), Maritime Systems (NET-02, PE 0603764E), and other programs that satisfy defense requirements for secure, survivable, and network centric systems. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602301E, Project ST-24 and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|-------------------------|---------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Fault Tolerant Networks | (2.191) | 2.000 | 0.000 | 0.000 |

(U) The primary goal of the Fault Tolerant Networks program is 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. The program also seeks a number of different networking protocols and technologies that will improve network security and provide quantitative statistical metrics that allow for the objective evaluation of network performance when

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fault condition exists or attacks are on-going or suspected. These technologies are reducing the amount of damage sustained during an attack, allowing networks to maintain an acceptable, minimum level of functionality. Technologies for strengthening networks have been developed by introducing fault tolerance capabilities against possible attacks at the network level, emphasizing integrity and availability. In addition, technologies for mitigating potential vulnerabilities associated with denial of service attacks have been developed. The most promising of these technologies 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 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.
- Implement and evaluate distributed queuing in prototype router hardware while continuing fundamental studies of distributed queuing algorithms, with a focus on algorithms that support reservation-oriented traffic.
- Develop 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------|---------|---------|---------|---------|
| Dynamic Coalitions | (2.009) | 2.000 | 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.
- Experimentally prove 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.
- Demonstrate 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|---------|---------|---------|---------|
| Partners in Experimentation | (2.544) | 5.843 | 0.000 | 0.000 |

(U) The Partners in Experimentation program seeks to conduct security technology experimentation with operational military and coalition partners. As part of this effort, the program also seeks to develop relationships with partners that will lead to multi-application information sharing, as well as improving interoperability between the participating partners. Such experimentation may also lead to the development of technologies for distributed denial of service countermeasures and encryption techniques to secure email across multiple organizations working collaboratively. Operational experimentation will also seek to provide valuable feedback to the security technology research and development process, which will demonstrate to operational personnel the benefits of advanced technology, and accelerate technology transition.

(U) 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.
- Evaluate performance and scalability of lab-proven anomaly detection techniques for intrusion detection in real-world, high-volume environments.
- Demonstrate network monitoring and Distributed Denial of Service (DDoS) countermeasures.
- Demonstrate multi-application cross-domain information sharing capability.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|---------|---------|---------|---------|
| Next Generation Optical Networks | (5.556) | 7.521 | 5.754 | 6.023 |

(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 photonic's 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: the elimination of data flow bottlenecks through the creation of optical network hardware that minimizes the occurrence of optical-to-electrical-to-optical conversions, network management tools that guarantee optimization of high density optical channels such as those provided by wavelength division multiplexing, the creation of a new class of protocols that permit the cross-layer communications needed to support quality-of-service requirements of high-priority national defense applications, and 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) A companion program, the Millimeter Wave Networks project, is developing new technology to make the upper millimeter wave (MMW) region affordable for proliferated use in an operational environment. This project is leveraging 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 with regeneration capability and optical wavelength switching.
 - Conduct network data flow/bottleneck analysis, 10 Gb/s to end user.
 - Develop switch architecture design for zero-apparent-jitter real-time applications.
 - Develop national testbed hardware specification, local area to wide area network integration, with data-format independence.
 - Protocol development for physical layer-to-application layer connectivity.

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- Demonstrate the ability to manage frequency and enforce low probability of detection limits.
- Enable the interface between optically switched backbone networks and conventional networks.
- Provide routing services for optically switched networks.

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Dynamic Quarantine of Computer-Based Worms (was Dynamic Quarantine of Worms) | (10.438) | 14.807 | 18.643 | 17.321 |

(U) The goal of the Dynamic Quarantine of Computer-Based Worms (formerly known as Dynamic Quarantine of Worms) 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 epidemiology, and provide off-line rapid response forensic analysis of malicious code to identify its capabilities, modalities, 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.

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- (U) Program Plans:
- Develop automatic detection and quarantine mechanisms.
 - Provide real-time and off-line analysis capabilities.
 - Develop emulated wireless mobility testbed.
 - Develop host and network-based detection and quarantine sensors/actuators.
 - Develop application re-provisioning services for failed nodes.
 - Verify integrated system capabilities.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------|---------|---------|---------|---------|
| Trustworthy Systems | (6.854) | 9.996 | 12.534 | 14.523 |

(U) The goal of the Trustworthy Systems program is to provide foundational trustworthy computer platforms for tactical military applications. 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. This includes the ability to process multiple classification levels with insecure data and programs on the same platform.

(U) The exemplar system being developed under this program is a handheld wireless personal digital assistant for network centric applications that would permit concurrent operation of situational awareness and command & control applications with unclassified and untrusted Internet/NIPRNET applications. The device could take classified data feeds of multiple classification levels, provide guaranteed separation, authorized cross-domain transactions with assurance of no cross-contamination (e.g., Unclassified – Secret and vice versa), and restrict data to the level that only the user is authorized to see. Innovations from this effort would eliminate traditional red-black separation architectures and short-circuit the long, arduous but fallible certification procedure for multi-level security systems. Additionally, this program will provide the U.S. Armed Forces with better network encryption devices that enable future coalition and joint force organizations to conduct network operations over multiple security domains without sacrificing network efficiency/speed.

(U) The traditional focus for encryption device development is high-speed encryption devices that can be installed on the backbone of the network. Unfortunately, these are expensive, coarse grained, difficult to configure and key, do not support access controls, and cannot be released

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to most of our allies. The Edge Encryptor effort will provide low-cost encryptors with fine-grained controls—a paradigm shift with respect to our current encryption methods. In addition, these devices will enable better interoperability and data exchange between partners. Efforts to devise and implement improved policy changes will be pursued that will allow these improved encryption devices to be used to encrypt U.S. classified traffic as long as that traffic remains on a U.S. installation.

(U) Finally, the Secure Group Communications effort will develop the mathematical models required for successful evaluation of secure communicating systems. It will focus on the dual aspects of design and analysis of authentication protocols.

(U) Program Plans:

- Trustworthy Systems.
 - Develop hardware, firmware, and microkernel architectures as necessary to provide guaranteed separation of data as necessary.
 - Develop assured cross-domain sharing of information.
 - Develop proofs of separation.
 - Engineer device with notional applications.
 - Conduct Red Team assessments and demonstrate the technology’s utility.

- Edge Encryptors.
 - Design and certify improved encryption devices that are able to work with current and projected network equipment and anticipated technologies and be releasable to coalition partners.
 - Demonstrate the ability to support wire keying/re-keying.
 - Develop certification and transition plans for these improved encryption devices.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| DARPA Future Information Assurance Initiatives | (0.000) | 4.569 | 4.135 | 5.025 |

(U) DARPA has been at the forefront of advancing the state of the art for information assurance technologies. Many of today's commercial practices have their roots in previous DARPA investments. As the DoD continues to be reliant upon commercial networks it is paramount that DARPA continue to look forward and investigate promising technologies. The 21st century transformation of the U.S. military will be more

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dependent on information technology for C⁴ISR and combat functions than perhaps any other aspect of the military. To a large extent, future combat systems will be more dependent on information than armor to accomplish missions successfully. The Department's vision for the future includes near-perfect knowledge of the battlespace and the ability to fight wars with information technology that enables remote C⁴ISR 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 to do so. 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, non-repudiation, and others.
- Develop the ability of individual hosts (end-points) to learn essential characteristics about the network path between themselves and their transmission partners.
- Develop an operating system with higher assurance, higher performance, and higher functionality than current A1 systems.
- Develop computing languages, compilers, and systems capable of producing executable code verified to be correct and bug free.
- Protection of Signaling Networks: Develop the ability to protect the core signaling and control of converged networks running voice over IP (VOIP), 3G wireless, and voice, and data networks in the backbone telecommunications switching fabric.
- Identify hosts securely and authoritatively 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 small, lightweight encryption device that is usable for coalition SECRET and below information that is low cost, self-configuring, and releasable to coalition partners.

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- Develop a wireless protocol that securely provides location, authentication, and communications in a practical manner.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------|---------|---------|---------|---------|
| Control Plane | (3.005) | 3.597 | 5.752 | 7.569 |

(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 path between themselves and other hosts, allowing the hosts to shape any transmission to pass through the network with the minimal network load. Additionally, when multiple network paths are available, a host will be able to either choose the path that best meets its requirements or simultaneously transmit over multiple paths. This technology will support the Defense Department's Global Information Grid concept of operations.

(U) Program Plans:

- Develop mechanisms to improve end-to-end Transmission Control Protocol and Internet Protocol (TCP/IP) 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.
- Develop the ability of hosts to learn about more than one possible path, choose the one which suits their needs best, and use it.
- Develop the ability of a host to simultaneously use multiple network paths for the same data transmission with the same partner, increasing communications speed and reliability.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Wide Area Network (WAN) Monitoring (formerly Asymmetric Firewalls) | (0.000) | 3.365 | 6.178 | 6.369 |

(U) The WAN Monitoring effort seeks to develop distributed network monitoring devices that can be used to identify traffic flows over the WAN. To do this, the system must deal with asymmetric flows and act to overcome these skewed flows with negligible impact on the network.

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The envisioned technologies include hardware devices for high-speed communications links and software-based changes for slower links. These devices and supporting software code will correctly monitor symmetric flows while simultaneously coordinating with similar devices embedded elsewhere in the network to monitor asymmetric flows. The technology to monitor WAN traffic at the packet, flow, session and application does not currently exist. Being able to monitor and stop unwanted traffic on the WAN and network backbones will dramatically improve network defense.

(U) Program Plans:

- Collect data to enable management and analysis of flows, session, and applications.
- Collect data that enables management and analysis of individual workstations and enclaves within Defense Department networks.
- Develop protocols, devices, and software that will analyze traffic at the packet, session, and application layer level.
- Develop high-speed distributed cueing systems to identify symmetric and asymmetric flow conditions/locations and that will stop unwanted connections across wide area networks before these connections are completed.
- Develop software that aids in the detection/mitigation of asymmetric flows.
- Develop high-speed hardware devices that aid in the detection/mitigation of asymmetric flows throughout the network.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Code and Network Vulnerability Testing Methodologies | (0.000) | 0.000 | 4.325 | 4.956 |

(U) The goal of the Code and Network Vulnerability Testing Methodologies program is to establish an institute to research network phenomena by providing tools, techniques, and methodologies for testing networked computer systems for vulnerabilities. Such an institute is envisioned as a key asset to relevant DoD/U.S. Government agencies whose charter includes seeking to ensure access to information systems, maintaining the U.S. edge in information operations, leveraging advances in information technologies, and ensuring DoD's ability to provide end-to-end interoperable communications in the long-term. The institute would develop the techniques and formal methods to validate the 'networthiness' of networked weapons systems. Currently, software/firmware/hardware systems can be checked for correct behavior and code security at the individual program or module level. However, once these systems are integrated into a network, they are assumed to work correctly across the network. Generally, there is no effort to validate this assumption and there are no established procedures or methodologies to validate these systems. As a result, the Defense Department's reliance on networks for future operations may be jeopardized.

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- (U) Program Plans:
- Working with likely DoD transition partners, such as the Defense Information Systems Agency (DISA) or the Directorate of Test and Evaluation (DOT&E), establish goals, evaluation criteria and metrics needed to thoroughly vet potential research institutes.
 - Finalize transition plans and agreements with transition partner(s) and obtain approval from USD, Acquisition, Technology and Logistics.
 - Select and establish a research institute at a university or non-profit organization that best meets all desired criteria.
 - Complete transition to DoD partner as the institute gains operational functionality.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------------|---------|---------|---------|---------|
| Remote Direct Memory Access (RDMA) | (0.000) | 0.000 | 5.623 | 7.250 |

(U) The Remote Direct Memory Access (RDMA) Protocol Termination Engine (PTE) project is a new and efficient way to develop hardware and software technology that removes the end-system protocol termination bottleneck that limits system access network bandwidth and degrades quality of service delivered to applications. This effort will develop hardware and software to implement these functions on a network interface card rather than in the host processor as is currently the case. The hardware is an ASIC chip implemented in Complementary Metal Oxide Semiconductor (CMOS) that protocol terminates open-standard 10GbE and supports remote direct memory access (RDMA). The software is device driver software that supports the hardware and minimizes loading the system host. The RDMA PTE (RPTE) technology that will be developed enables a wide range of new interoperable open-standards based applications for high performance military systems that use 10 Gb/s broadband networks.

- (U) Program Plans:
- Complete design and documentation of the micro-architecture and software specification for the RPTE interface card.
 - Complete design and documentation of the PTE implemented in the Field Programmable Gate Arrays (FPGA).
 - Simulate RPTE performance in a wide range of applications and compare the results to a conventional approach.
 - Fabricate RPTE chips and cards.
 - Demonstrate RPTE system.

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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, Project IT-04 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Language Translation IT-04 | 0.000 | 57.389 | 65.744 | 69.687 | 75.221 | 75.593 | 65.593 | 60.593 |

(U) Mission Description:

(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. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602301E, Project ST-29, and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|--|----------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Situation Presentation and Interaction | (10.870) | 11.500 | 11.616 | 14.387 |

(U) There are two programs involving direct speech-to-speech translation:

- The Compact Aids for Speech Translation (CAST) program is providing the tactical warfighter with real-time, face-to-face speech translation during combat and humanitarian operations in foreign territories. The program addresses domain-specific translation accuracy and response time. Early CAST prototypes relied on simple dictionaries and phrases. The CAST program resulted primarily in quickly making one-way translation systems (from English to multiple foreign languages) available to warfighters in the field. The DARPA Phraselator is the key prototype system in use today. The system was deployed in Operation Iraqi Freedom and Operation Enduring Freedom. Future versions will offer a more sophisticated, flexible and fluid translation and paraphrasing capability that is robust and conducive to normal human conversations.

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- 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 CAST 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:
- Compact Aids for Speech Translation.
 - Integrated speech recognition engines into natural language parsers and translators.
 - Produced prototype translation devices in three languages (Pashto, Farsi, and Mandarin Chinese).
 - Performed initial coordination with U.S. Army PM Soldier for software integration into land warrior Block III (version 3.0).
 - Populated the language digital resource repository at Defense Language Institute.
 - TRANSTAC.
 - 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.
 - Demonstrate 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 ongoing in-field language data collection.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Automated Speech and Text Exploitation in Multiple Languages | (43.542) | 45.889 | 54.128 | 55.300 |

(U) There are three programs involving the exploitation of naturally occurring speech and text:

- Translingual Information Detection, Extraction and Summarization (TIDES) is revolutionizing the way time-critical intelligence is obtained from speech and text. The program has been developing technology to enable English-speaking operators and analysts to exploit the huge amounts of foreign speech and text (broadcast and newswire) that currently go unanalyzed due to shortages of skilled foreign language analysts. TIDES is creating 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). TIDES technology will dramatically increase the quantity, quality, and timeliness of analysis and reporting, thereby providing vital information to senior decision-makers and enabling commanders to carry out critical missions more swiftly, safely, and effectively.
- Effective, Affordable, Reusable Speech-To-Text (EARS) is creating new automatic transcription (speech-to-text) technology whose output is substantially richer and more accurate than previously possible. Fast, accurate, automatic transcription of broadcasts, telephone conversations and multiparty speech will make rapid search and analysis of speech possible. EARS also provides text versions of spoken language for input to systems developed in TIDES, thereby extending the scope of what is possible with automatic translation, detection, extraction, and summarization.
- 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 off of 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. Captured documents will be converted into readable, searchable English text.

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(U) Program Plans:

- Translingual Information Detection, Extraction and Summarization (TIDES).
 - Demonstrated the ability to detect and track events described in English, Arabic and Chinese news sources.
 - Demonstrated the ability to extract information from English, Arabic and Chinese news sources.
 - Demonstrated the ability to translate Arabic newswire text into readable English.
 - Transitioned successful components to CENTCOM.
 - Developed methods for porting TIDES technology to new languages.

- Effective Affordable Reusable Speech-To-Text (EARS).
 - Substantially improved the speed and accuracy of automatic transcription for broadcasts and conversations in English.
 - Improve the speed of automatic transcription to real time.
 - Develop automatic techniques to produce rich, readable transcripts of broadcasts and telephone conversations in English, Chinese, and Arabic.
 - Develop automatic techniques to produce rich, readable, searchable transcripts of multiparty speech from command centers, teleconferences and meetings.

- Create and evaluate technology demonstration prototypes.

- Global Autonomous Language Exploitation (GALE).
 - Develop technology to convert huge volumes of streaming speech and text in multiple languages to English text.
 - Develop technology to distill critical intelligence from that English text.
 - Develop technology to convert captured documents into readable and searchable English.
 - Insert these technologies and systems into high-impact military and intelligence operational centers.

(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 Cognitive Computing Systems PE 0602304E, R-1 # 13 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 0.000 | 149.782 | 200.799 | 241.006 | 263.375 | 274.243 | 301.243 | 309.243 |
| Cognitive Systems Computing Foundations COG-01 | 0.000 | 27.552 | 33.678 | 37.710 | 41.284 | 41.751 | 56.751 | 56.751 |
| Learning, Reasoning, and Integrated Cognitive Systems COG-02 | 0.000 | 81.797 | 113.931 | 141.780 | 160.865 | 170.741 | 180.741 | 190.741 |
| Collective Cognitive Systems and Interfaces COG-03 | 0.000 | 40.433 | 53.190 | 61.516 | 61.226 | 61.751 | 63.751 | 61.751 |

(U) Mission Description:

(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. This program element and the projects funded within it were created in accordance with congressional intent in the FY 2005 DoD appropriations bill with prior year funding budgeted in PE 0602301E, Projects ST-30, ST-31, and ST-32.

(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.

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(U) The Learning, Reasoning, and Integrated Cognitive Systems 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.

(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.

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|------------|--|-----------------------|----------------------|----------------------|
| (U) | <u>Program Change Summary:</u> <i>(In Millions)</i> | <u>FY 2005</u> | <u>FY2006</u> | <u>FY2007</u> |
| | Previous President's Budget | 151.158 | 182.054 | 221.877 |
| | Current Budget | 149.782 | 200.799 | 241.006 |
| | Total Adjustments | -1.376 | 18.745 | 19.129 |

Please note that this program element has been newly created from projects previously funded in PE 0602301E. The *previous President's Budget* amount reflects projects ST-30, ST-31 and ST-32 funded under that PE.

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| Congressional program reductions | -1.376 |
| Congressional increases | 0.000 |
| Reprogrammings | 0.000 |
| SBIR/STTR transfer | 0.000 |

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(U) Change Summary Explanation:

FY 2005 The decrease reflects congressional undistributed reductions.
FY 2006 - 2007 The increase reflects expansion of learning programs in project COG-02 and collaborative cognition efforts in project COG-03.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | | | R-1 ITEM NOMENCLATURE Cognitive Computing Systems PE 0602304E, Project COG-01 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Cognitive Systems Foundations COG-01 | 0.000 | 27.552 | 33.678 | 37.710 | 41.284 | 41.751 | 56.751 | 56.751 |

(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, mix 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 novel forms of computation developed in Cognitive Systems will revolutionize future military systems. Next-generation 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. The Cognitive Systems Foundations project will develop the necessary foundational software methods and hardware architectures to facilitate the learning and inference 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 new 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. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602301E, Project ST-32 and is noted as a memo entry in each of the following programs.

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(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Architectures for Cognitive Information Processing | (8.808) | 11.628 | 12.678 | 15.715 |

(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:

- Select innovative computer architecture(s) and in-context applications for cognitive architecture implementations, demonstration 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Self-Regenerative Systems | (7.423) | 9.821 | 12.000 | 12.300 |

(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. SRS technology 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. Beyond graceful degradation capabilities provided by fault- and intrusion-tolerance mechanisms developed in prior DARPA programs, 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. They will also maintain robustness and trustworthiness attributes even with growth and evolution in functionality and performance.

(U) Program Plans:

- 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.
- Demonstrate scalable data redundancy for network-centric military applications and infrastructure services, and develop techniques for natural robustness via biological metaphors to counter vulnerabilities of monoculture in military information systems.
- Develop techniques for natural robustness via biological metaphors to counter vulnerabilities of software monocultures in military information systems.
- Develop strategies to preempt insider attacks, including infer military system operator goals, enable anomaly detection, combine and correlate information from system layers and use direct user challenges.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------|---------|---------|---------|---------|
| Security-Aware Systems | (4.163) | 6.103 | 9.000 | 9.695 |

(U) Today's military software systems are brittle in the face of changing requirements, and vulnerable to skilled attackers who develop creative and unpredictable strategies. Security-aware systems will avoid brittleness and vulnerability by reasoning about their own security attributes, capabilities and functions with respect to specific mission needs. Security-aware 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. In addition, 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.

(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 provides 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 general-purpose information systems and reduce the threat from stealth attacks where attackers take control of systems undetected. In addition, this program will develop quantitative information assurance measurement techniques to enable military system integrators to construct networks and information systems with a high degree of confidence that the systems are protected against cyber-attacks (by the assurance properties of available components). The technology will greatly enhance the reliability and security of C4ISR systems.

(U) Program Plans:

- 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 that the descriptions produced by AC can be understood while at the same time not omitting critical details.

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- 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 techniques to collaboratively diagnose and respond to problems (e.g., attacks or failures that threaten a mission) in groups of military systems.
- 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.
- Demonstrate cognitive security analysis of complex multi-component software systems.
- Create an extensible knowledge base of embedded system design flaws.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Learning, Reasoning and Integrated Cognitive Systems COG-02 | 0.000 | 81.797 | 113.931 | 141.780 | 160.865 | 170.741 | 180.741 | 190.741 |

(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 degradation or failure and mission success, 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 Learning, Reasoning and Integrated Cognitive Systems 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 human 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. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602301E, Project ST-30 and is noted as a memo entry in each program below.

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(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------|----------|---------|---------|---------|
| Integrated Cognitive Systems | (31.046) | 45.409 | 57.192 | 63.063 |

(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 thrust comprises the Personalized Assistant that Learns (PAL) and Cognitive Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance (Cognitive C4ISR) programs.

- 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

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intermediate preferences and constraints on system behavior, to specific direction and contingency actions. The end-user will be able to engage in a natural dialogue with the system, and the advice will be translated to an executable form.

- The Cognitive Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance (Cognitive C4ISR) program will develop embedded learning and real-time reasoning elements along with multimodal dialog-based interfaces to enable a new generation of cognitive C4ISR. These technologies will support effective decision-making in the face of the increased pressures, ambiguity, deception and surprise of today's military operations. The embedded learning element will provide faster response times by allowing a system to retain and apply what it has learned in the past. Real-time reasoning allows the system to apply what has been learned to new scenarios in an intelligent and thorough way. The multimodal dialogue technology transition to the military will emphasize adaptable and scalable architectures and automatic dialogue that addresses human stress adaptation, prosody and system reliability. The Cognitive C4ISR transition efforts will assist commanders by providing critical information in a timely manner, with alternative courses or action, to enable more effective decision-making.

(U) Program Plans:

- Personalized Assistant that Learns.
 - Developed baseline architecture for a complete PAL system.
 - Developed an initial knowledge base representing a PAL system's task domain.
 - Developed initial technology for a PAL system to interact with its user and enable the system to perceive activities over time and develop an understanding of user preferences and basic operational procedures.
 - Develop mixed-initiative technology that enables a PAL system to ask appropriate questions at appropriate times when confidence in an inference is below threshold.
 - Develop and demonstrate core machine learning, knowledge base and flexible planning technologies to enable development of a cognitive planning agent.
 - Develop and demonstrate 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 the ability for an integrated cognitive system to examine its own behavior and learn from that experience.

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- Develop test problems, define metrics, and conduct formal experiments to evaluate progress in integrated cognitive systems technology R&D.
 - Develop compelling scenarios to drive advisable technology research through a series of increasingly difficult challenge problems.
 - 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.
- Cognitive C4ISR.
- Develop technologies to enable a system to draw inferences from mission-defined rules of operation for situational awareness from which a course of action may be suggested.
 - Develop a common architecture and integration technologies that will examine and characterize the influences and interactions among the organization structure, its staff, tasks and technology.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|----------|---------|---------|---------|
| Foundational Learning Technology | (11.112) | 26.224 | 38.830 | 55.282 |

(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 comprises Real-World Learning, Bio-Inspired Cognition, and Learning Locomotion and Navigation.

- The Real-World Learning thrust 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 the ability to transfer knowledge and skills learned for specific situations to novel, unanticipated situations and perform appropriately and effectively the first

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time a 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 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. Cognitive systems 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. Real-World Learning will enable systems to execute unanticipated tasks with minimal direction and will provide a much-needed military capability for coping with dangerous and unpredictable situations.

- The Bio-Inspired Cognition thrust (formerly Neuromorphic Learning Technology) 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/sensor 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.
- The Learning Locomotion and Navigation thrust will develop learning and reasoning technologies that specifically address concerns in robotic systems. The resulting robotic systems will learn automatically 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, surveillance and reconnaissance, and will dramatically advance the capabilities of autonomous vehicles. Tasks requiring

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higher-level computation, such as perception-based navigation, will also benefit. This thrust comprises two components: Learning Applied to Ground Robots (navigation) and Learning Locomotion.

(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 generation of specific and novel situations to use for evaluating 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; to adapt to a wide variety of naturally-occurring situations; and to 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.
 - 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 and skills acquired for one purpose to other purposes, and demonstrate the ability to propose novel problem solution methods when specified resources are unavailable.
 - 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.
 - Create methods for using domain knowledge to guide and direct learning algorithms.
 - 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.

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- 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 two test batteries for testing and evaluating cognitive architectures: a “cognitive decathlon” for assessing specific skills associated with cognition (e.g., visual perception, memory); and a set of challenge problems, each of which will require a complex range of cognitive functions in order to be successfully negotiated.
 - Using these batteries, compare the performance of biomorphic learning technologies against those of traditional artificial intelligence.

- 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------|---------|---------|---------|---------|
| Knowledge-Based Technology | (5.647) | 10.164 | 17.909 | 23.435 |

(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-Base 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 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 some new ways for knowledge to be transferred efficiently to a knowledge base including 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 store knowledge about the choices the warfighter has made in the past, so when faced with a similar task, the system would select a performance method by referring back to previous decisions. Although not appropriate for all cognitive systems tasks, this action-

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centric technique should be effective for simple tasks, such as information gathering to support mission planning or intelligence analysis. Most cognitive research is predicated on explicit representation (i.e., having models of the world) and reasoning about the way to achieve a specific goal or meet specific need. While this approach is effective, encoding the knowledge and reasoning procedures is labor intensive and expensive. This program will develop a new technique that eliminates the material investment required by traditional approaches. This approach will replace deep reasoning and deep semantics with implicit reasoning and semantics derived from actual warfighter performance and experience.

(U) Program Plans:

- Knowledge-Based Systems.
 - Develop 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. 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.
 - Explore novel methods for acquiring new knowledge that are less onerous than traditional methods requiring hand-coding by experts including direct input through processing natural language text.
- 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 the performer and store these operations along with the implicit semantic knowledge in a repository for future automation.

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

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Collective Cognitive Systems and Interfaces COG-03 | 0.000 | 40.433 | 53.190 | 61.516 | 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, which 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 to take advantage of the power of collective cognitive agents.

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(U) The suite of programs conducted under project will significantly advance the military’s ability to address and deal with complex situations in operational environments. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602301E, Project ST-31 and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Improved Warfighter Information Processing | (21.206) | 12.763 | 12.112 | 0.000 |

(U) The Improved Warfighter Information Processing (IWIP) technology thrust will develop technologies to enhance the warfighter’s and commander’s information management capacities and improve decision-making performance. This thrust will develop technologies to enable systems to detect and assess the user’s cognitive state (e.g., level of attention, memory retention, and decision-making capabilities) and adapt to optimize the user’s understanding and productivity. The work will significantly expand the warfighters’ capabilities in a real-time operational environment by enhancing information throughput and retention, and executive function efficiency. This thrust will also help create context-based computational systems that will understand, predict and participate in goal-directed collaboration to maintain situational awareness and assist the warfighter in the decision-making process. Recent progress in neural science, computation and miniaturization can now be leveraged to enable new concepts of warfare. The technologies developed under this thrust will revolutionize the way 21st Century warriors and commanders interact with computer-based systems, implement advanced systems design methodologies, and fundamentally re-engineer military decision-making processes. The IWIP thrust comprises two programs: Improving Warfighter Information Intake under Stress and Context-Based Computing for Command and Control.

- 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

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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 will also pursue 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 an MOA with the U. S. Army Soldier and Biological Chemical Command and the Naval Air Systems Command for transition of this program.

- The Context-Based Computing for Command and Control (CBC³) program will demonstrate dramatic improvements in command decision-making and situational awareness, in real time, based on the development of “context-based computing.” CBC³ will also capture, in real time, the context (situation assessment including information about places, people, time, functional activities, etc.) critical for supporting the decision-maker. Software tools and agent services will be provided to support the rapid creation of interoperability capabilities for information exchange in heterogeneous environments. The long-term impact of this work will be to provide users with vastly expanded expressive power, interface flexibility and transparency, timely access to relevant information, and greater overall utility and robustness of interaction with next-generation military digital systems.

(U) Program Plans:

- Improving Warfighter Information Intake under Stress.
 - 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.
 - 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.

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- Quantify and characterize 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.
- 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 proactive information manipulation and presentation.

- Context-Based Computing for Command and Control.
 - Identify decision-making bottlenecks, impediments, and information exchanges in specific command and control settings in the context of on-going military and non-military operations; define operational metrics for decision-making.
 - Develop techniques for capturing the context of military command and control center operations to enable intelligent information management.
 - Elaborate interfaces into full-fledged “decision-interactive spaces” to illustrate the full power of decision-focused computing for command and control.
 - Allow for the flexible adaptation of policy and protocol in information exchange and the issuing of orders; allow for interoperability across disparate security domains.
 - Integrate interoperable agent-based technologies into existing military operations to provide secure and easy-to-use solutions.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------|---------|---------|---------|---------|
| Collaborative Cognition | (7.780) | 15.232 | 20.204 | 26.383 |

(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 in dynamic environments that 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 and prediction tools, and other aids to human decision-making. The technology developed 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 three programs: Collaborative Cognition Systems, Coordination Decision-Support Assistants (COORDINATORs), and Advanced Soldier Sensor Information System and Technology (ASSIST).

- The Collaborative Cognition Systems program will develop software for controlling agent computer programs capable of interacting with both friendly and adversarial software agents, and operating in multiple domains and/or varying scenarios within the same domain. The application of learning and reasoning technology in an explicitly collaborative setting will allow systems to modify themselves based on experience and information exchanged among multiple team members; this will enable adept control of agent programs under previously unseen or unknown conditions. This work will also explore revolutionary concepts for applying distributed agent technology to modeling and simulation systems. The long-term goal is to apply this technology to operational environments, thereby significantly advancing deployed system capabilities.
- 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 and conflict situation by keeping track of 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 with far fewer

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personnel required in the re-planning coordination 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.

- A key lesson learned from Operation Iraqi Freedom 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 Iraqi 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:

- Collaborative Cognition Systems.
 - Develop a strategic control language to specify the behaviors of individual software agents and teams of agents regardless of their low-level implementations.
 - Develop plug-and-play modules for cognitive processes and primitive behaviors to increase the intelligence of software agents in simulation and autonomous systems.
 - Create an ability for software agents to monitor, assess and explain the situation in the environment to support autonomous and collaborative behavior with other agents and warfighters-in-the-loop.

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- 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 can self-direct option generation when the human units are occupied or uninterruptible.
 - Develop a meta-cognition technology that reasons about resource allocation (i.e., where a given COORDINATOR should spend its processing time), so that 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 that COORDINATORS follow correct information exchange protocols and ensure that decisions and recommendations stay within the scope of authorization.

- Advanced Soldier Sensor Information System and Technology (ASSIST).
 - Demonstrate 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 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Self-Sufficient Collective Systems (formerly "Self-Aware Collective Systems") | (1.949) | 2.338 | 4.781 | 9.422 |

(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 a specific task. 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.

(U) The Cognitive Collectives for Autonomic Situation Awareness thrust will create software technologies that enable future warfighters to form a collective unit and share information automatically. This will provide the warfighters with a broad tactical battlespace awareness. The selection, generation, sharing and display of information will be handled by cognitive software systems coupled with each warfighter. The network of individual systems will form a collective. Each system will monitor the sensors attached to its 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.

(U) Program Plans:

- Cognitive Collectives for Autonomic Situation Awareness.
 - 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------|---------|---------|---------|---------|
| Cognitive Networking | (9.072) | 10.100 | 16.093 | 25.711 |

(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 communication based on current conditions, past experience and high-level user guidance. The Cognitive Networking thrust comprises three programs: Universal Adaptive Controller for Mission-Aware Ad-Hoc Networks, Self-Sustaining Peer-to-Peer Systems, and Situation-Aware Protocols in Edge Network Technologies.

(U) An outgrowth of the Adaptive Networking program, the Universal Adaptive Controller for Mission-Aware Ad-Hoc Networks (UNMAN) program will develop an adaptive configuration management capability that dramatically reduces life-threatening communication failures in complex communication networks. In order to develop this new capability, the initial focus is on the tactical mobile ad-hoc networks (MANETs). As are other critical networks, MANETs are composed of interdependent nodes based on interdependent system layers. Each node exposes dozens 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. Furthermore, today’s commercial trends are not aimed at supporting the DoD’s extreme deployments. This program will take on the ambitious goal of addressing the integrated management of all network layers simultaneously. Key technical challenges include mission understanding and mapping mission requirements to goals for each of the network’s agents in order to optimize instantaneous resource allocation. These challenges are particularly difficult in a distributed setting with partial and uncertain information, high communications overhead, and high probability of failure. To address this problem, the UNMAN program will develop new mission-aware, adaptive, distributed, active learning and reasoning technologies that will provide a robust and effective configuration capability for MANETs.

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(U) The Self-Sustaining Peer-to-Peer Systems program, an outgrowth of the DARPA Networking program, will develop resilient, scalable sensor/computation/communication networks with decentralized control. This technology will enable continuous monitoring of critical areas and targets in remote or inaccessible areas through the development of self-forming, large *ad hoc* networks of sensors and computational elements. Networks will operate within severely resource-constrained environments (power, bandwidth, stealth) of military operations, while enabling critical networks to survive component failure, network intrusion and the subversion of elements. This self-sustaining network of sensors and communication elements will provide a lifeline to the warfighter in the support of effective operations while automating the burdensome and distracting tasks of network deployment, configuration and management. High-level languages will be developed to map the warfighter’s mission plans, including geographical constraints and direct control of individual sensors, into network control actions. The cognitive network technology will provide on-demand sensing, imaging and tracking with a prediction/planning capability to estimate the state and trustworthiness of network elements, communication links, and assets connected by sensors. Thus, as elements fail or are subverted, the Self-Sustaining Peer-to-Peer Systems will control the graceful degradation of any of its parts. The program will develop network technology for terabit data streaming and processing, on-demand networking and methods for mobile, data-centric ad-hoc networks. This technology will support a variety of networks of manned and unmanned systems.

(U) 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 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 and demonstrate 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.

- (U) Program Plans:
- Universal Adaptive Controller for Mission-Aware Ad-Hoc Networks.
 - Identify and characterize the major components of an adaptive/cognitive network and software functionality for large-scale redesign.

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- Demonstrate the operation of multiple cognitive radios as a team operating as a single unit.
- Automatically respond to dynamics associated with mission, capabilities and location.
- Design and develop appropriate interfaces between the two architectural components of a cognitive network: the “mission understanding” layer and the “adaptive control” layer.
- Develop and demonstrate multi-level learning capabilities that can perform active learning and empirical optimization of resource allocations in mobile ad-hoc networks.
- Develop and demonstrate mission understanding and adaptive control capabilities that can drive resource allocation in mobile ad-hoc networks.

- Self-Sustaining Peer-to-Peer Systems.
 - Define and develop cognitive representations and distributed agent technologies, information fusion, diagnostic and prognostic algorithms, network control language, and network benchmarks.
 - Integrate image recognition, adaptive radio frequencies (RF) and other sensors, and advanced signal processing for scene analysis and information extraction from sensors allowing operator input to be incorporated as necessary.
 - Develop a dynamic architecture that defines logic, belief representation, cognitive network protocols, and adaptive target recognition and negotiation techniques.
 - Develop mathematical models and algorithms to synthesize intelligent, self-sustaining, self-forming networks allowing for distributed control; synthesize global models based on distributed local inputs, and to improve over time using learning technology such as reinforcement learning and Bayes Nets.
 - Initiate the development/demonstration of robust, secure, self-forming tactical networks.
 - Develop software models and tools for massive data streaming and processing.
 - Develop novel 3-D network management software for collaborative information processing and conversion of raw sensor data, detection, classification, tracking and event correlation to support integrated micro-sensor framework for mobile and on demand networks.

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- Situation-Aware Protocols in Edge Network Technologies.
 - Create 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.
 - Develop a suite of fundamental protocol components appropriate for these situations.
 - Develop and implement a selection and composition methodology to exploit situation awareness to construct a functioning network protocol adapted to the situation.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------|---------|---------|---------|---------|
| Network Modeling and Simulation | (4.249) | 0.000 | 0.000 | 0.000 |

(U) The Network Modeling and Simulation (NMS) program developed software to enable prediction of performance; design; and control of complex networks over a broad range of time scales, network sizes, composition and performance. These models and simulators are enabling reliable and rapid planning, design, analysis, and configuration of military and emergency networks with minimal manual intervention. They have already transitioned to a number of military users, and are currently finding increasing interest in the DoD community.

(U) Program Plans:

- Developed the largest, fastest network simulation to date. Demonstrated a simulation of millions of nodes in near real time. Developed a hybrid simulator integrating fluid and multi-fractal models. Achieved 100x scalability in network size, 50-100x speed in simulation over sequential techniques, for both wired and wireless networks.
- Implemented measurement and simulation based, on-line prediction of core Internet, and border gateway protocol, stability and vulnerability, including that arising from virus propagation.
- Developed a simulator suitable for on-line network analysis and control, and scalable to tens of thousands of nodes.
- Demonstrated on line network controls including quality-of-service provisioning and dynamic reconfiguration.
- Demonstrated 10 to 100 x improvements in time to field new protocols, fault and vulnerability diagnosis, over operator-intensive current techniques.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | R-1 ITEM NOMENCLATURE Cognitive Computing Systems PE 0602304E, Project COG-03 | |

- Transitioned simulation software to DoD clients including DISA, DMSO, FCS, Navy, Air-Force, JFCOM and other service agencies, for use in applications including infrastructure protection, rapid battlefield network design, and network management and control.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | | | R-1 ITEM NOMENCLATURE Biological Warfare Defense PE 0602383E, R-1 # 14 | | | | |
| COST (In Millions) | FY 2004 | FY2005 | FY2006 | FY2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 141.921 | 159.567 | 145.354 | 144.050 | 144.615 | 140.414 | 140.914 | 140.914 |
| Biological Warfare Defense Program BW-01 | 141.921 | 159.567 | 145.354 | 144.050 | 144.615 | 140.414 | 140.914 | 140.914 |

(U) Mission Description:

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

(U) Efforts to counter the BW threat include developing barriers to block entry of pathogens into the human body (including unique methods for rapid air and water purification), countermeasures to stop pathogen and chemical consequence and to modulate host immune response, medical diagnostics for the most virulent pathogens and their molecular mechanisms, biological and chemically-specific sensors, advanced decontamination and neutralization techniques, 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.

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(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|---------|---------|---------|---------|
| Unconventional Therapeutics | 42.961 | 38.533 | 37.202 | 38.300 |

(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 and a separate thrust in Accelerated Anthrax. 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. Because activation of the innate immune system also provides protection from oxidative DNA and cell membrane damage, these approaches are now known to provide protection against radiation exposure in animals. This thrust is also addressing the difficulty in demonstrating the efficacy of vaccines against threats that cannot undergo human trials through the development of tools such as an artificial immune system that will provide rapid, in vitro assessments of novel countermeasures against unique DoD threat agents.

(U) Program Plans:

- Demonstrated antibacterial activity of heterobiaryl guanidines and transitioned to U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID).
- Demonstrated the use of gene shuffling to restructure enzymes, proteins and other biological agents to make them more potent and transitioned to USAMRIID and the Navy.
- Demonstrated human acetyl cholinesterase production from transgenic plants and transitioned to USAMRIID.
- Identified and developed a new, broad spectrum antibiotic for pathogens targeting CcrM DNA methyltransferases and transitioned to USAMRIID.
- Demonstrated superantigen toxin antagonist and vaccines and transitioned to USAMRIID.
- Demonstrated nonspecific immune stimulation by synthetic lipid A analogues and transitioned to USAMRIID.
- Demonstrated that molecular database construction and mining is a powerful approach to developing unconventional pathogen countermeasures.

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- Establish a common test-bed for efficacy, safety and drug metabolism in FDA validated models.
- Discover broad-spectrum therapeutics that attack fundamental and common biochemical processes in bacteria and/or viruses.
- Explore mechanisms that induce innate immunity and early protection.
- Explore mechanisms of cellular control that are used by pathogens to mask identification.
- Develop therapeutic approaches that target host biochemistry to deny a broad range of pathogens (within or across classes) the opportunity to infect and cause disease thereby radically changing the prophylactic and therapeutic approach of the DoD to protecting the warfighter in hazardous environments.
- Exploit biochemical pathways to develop protective measures against radiation exposure.
- Develop the tools necessary for in vitro fabrication of three dimensional tissue constructs, bioscaffolds and bioreactors.
- 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.
- Examine new approaches to dramatically accelerate the time from discovery of a pathogen to production of a therapeutic.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------------|---------|---------|---------|---------|
| Acceleration of Anthrax Therapeutics | 4.000 | 0.000 | 0.000 | 0.000 |

(U) This thrust accelerated promising anthrax therapeutics (antibodies, immunostimulatory approaches and late stage treatment) into the FDA regulatory process and filed an Investigative New Drug (IND) application, which would allow the first human safety trials.

(U) Program Accomplishments:

- Demonstrated through clinical trials the efficacy of using CpG for enhancement of existing anthrax vaccine (AVA), reducing the required shot regimen from six to two.
- Demonstrated the regulation of pathogen gene expression by using DNA-binding polyamides to attack the AT rich DNA of pathogens.
- Demonstrated and brought to IND a small molecule that targets an enzyme necessary for bacterial DNA replication but that has no effect on human cell replication.
- Demonstrated and brought to an IND the use of bacteriophage enzyme specific to anthrax to lyse (disintegrate) anthrax bacteria.

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- Demonstrated and brought to an IND the use of Inhibitor of “protective antigen” that blocks the effect of anthrax toxin on a cell during the late stage of the disease.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------|---------|---------|---------|---------|
| External Protection | 6.000 | 11.000 | 15.500 | 17.000 |

(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. This includes novel water purification approaches, and the detection and cleaning of surfaces contaminated by an attack.

(U) Program Plans:

- Developed, tested and transitioned to the Services a water purification pen capable of disinfecting 300 liters of non-brackish water.
- Develop new approaches for self-decontaminating surfaces that will be self-cleaning and be able to deactivate spores.
- 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 new approaches for widespread external decontamination.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------|---------|---------|---------|---------|
| Advanced Diagnostics | 7.730 | 8.534 | 9.000 | 9.250 |

(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 efforts will develop the capability to detect the presence of infection by biological threat agents, differentiate them from other pathogens (including those of non-BW origin), and identify the pathogen even in the absence of recognizable clinical signs and symptoms (i.e., while the pathogen numbers are still low). Novel approaches including the use of breath and advanced mathematical analysis will be examined.

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- (U) Program Plans:
- 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 and demonstrate strategies for rapidly generating new probe panel procedures and analytical tools for obtaining and measuring relevant sample types (e.g., breath, blood). Adapt advances in biosensors as appropriate.
 - 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------|---------|---------|---------|---------|
| Sensors | 42.000 | 48.000 | 48.000 | 48.000 |

(U) The sensor 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) Handheld Isothermal Silver Standard Sensor (HISSS)
- 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 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.

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- (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:
- Designed and built “gold standard” laboratory instruments for high-volume data collection of agent and background signatures.
 - Developed and validated end-to-end performance model.
 - Completed proof-of-concept analysis and preliminary performance prediction in clutter.
 - Completed false alarm testing using complex environmental backgrounds.
 - Deployed proof-of-concept prototype to USAMRIID to evaluate performance, describe behavior in operational environments, and augment signature library with live agents and emerging infectious diseases.
 - Completed characterization of probability of detection and probability of false alarm performance in low- and high-background samples.
 - Developed chemically modified primers to support near-neighbor discrimination, strain typing and broad-range RNA virus identification.
 - Develop capability to perform phylogenetic classification of unknown or genetically modified organisms.

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- 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.

(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 interferences such as diesel smoke, pollen and natural fibers.
- Investigate spectral response of chemicals unique to BW agents (e.g., picolinic acid in anthrax spores).
- Collect data, and develop 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, evaluate use of mass spectrometry for particle identification.
- Downselect to most promising concepts; design, build, and test prototype sensor.
- Characterize prototype behavior in operational environments.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------|---------|---------|---------|---------|
| Immune Buildings | 25.030 | 21.000 | 12.500 | 10.000 |

(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 Wide-Area Radionuclide Detection (WARD) technologies to rapidly identify buildings contaminated with radioactive material and Radionuclide Capture Decontamination (RCD) technologies to rapidly remove radioactive contamination from those surfaces.
- Test WARD and RCD technologies on standardized coupons of representative building materials and demonstrate use at full scale.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Chem Bio Defense (CBD) Portal Security | 0.000 | 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 is investing 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 are being evaluated for their ability to penetrate package and container materials and obtain signatures for anomaly or hazard detection/identification. Novel destruction methods for BWAs are also being evaluated. In FY 2006, this program transitions to the OSD Chemical/Biological Defense Program, PE 0603384BP, Project TT3.

(U) Program Plans:

- Evaluate 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).

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- Select the most promising approaches, and use laboratory instrumentation to evaluate collateral damage and false alarms.
- Develop performance model, and carry out system trades and develop required prototypes/components.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Wide-Area BW Surveillance | 1.000 | 0.000 | 0.000 | 0.000 |

(U) The Wide-Area Biological Warfare Agent (BWA) Surveillance program investigated BWA surveillance systems architectures for urban environments, such as military bases and transportation centers, to effectively and efficiently detect covert aerosol releases of BWA and to determine the approximate release location *before the onset of symptoms in humans*. The program studied the key architecture trades, including: the appropriate mix of stationary and mobile assets (collectors/samplers and identification sensors); the value of distributed sampling and identification (sensing) versus distributed sampling with centralized identification; the role of layered sensing, such as continuous wide-area surveillance followed by focused/targeted collects for confirmation; the importance of spatial and temporal resolution in enabling backtracking to determine release time and release location; and specialized collection and identification requirements in different environments. These trades were carried out by modeling covert releases and then analyzing the ability of various architectures (1) to detect the release quickly and (2) to geo-locate the source. The results of these studies provided much of the analytical basis for the Threat Agent Cloud Tactical Intercept and Countermeasure (TACTIC) program.

(U) Program Plans:

- Conducted trade studies of potential detection architectures in selected urbanized areas; estimate system performance, including probability of detection and false alarm rates, with realistic measures and models of background biological clutter
- Developed analytic methods to geo-locate the BWA release source based on distributed detector system response and, realistic meteorological models.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Threat Agent Cloud Tactical Intercept Countermeasure (TACTIC) | 0.000 | 8.500 | 12.500 | 10.300 |

(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.
- Demonstrate system in full-scale field trials.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Mission-Adaptable Chemical Sensors (MACS) | 0.750 | 5.500 | 10.652 | 11.200 |

(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 is investigating the nature of the atmospheric background “clutter” at the parts per billion (ppb) level and below, which must be understood for 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:

- Determine the composition of the “clutter” background of the atmosphere at ppb levels.
- Demonstrate and calibrate improved sensitivity of apparatus for selected species.
- Demonstrate fractionation and related improvements to the system for simultaneous identification of multiple species in seconds.
- Demonstrate capability for dramatic reduction in size and weight of original system, with improved detection sensitivity and selectivity.
- Demonstrate feasibility of prototype portable system for field implementation.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Center for Water Security | 1.000 | 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------|---------|---------|---------|---------|
| Asymmetrical Products for BWD | 2.000 | 2.000 | 0.000 | 0.000 |

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------|---------|---------|---------|---------|
| Desalination Research | 2.550 | 0.000 | 0.000 | 0.000 |

- (U) Program Plans:
- Developed a non-traditional approach to large-scale desalination of seawater at the ocean shore near available liquid natural gas (LNG) or liquid methane storage facilities.
 - Enabled the formation of gas-hydrate-purified, near-potable water ready for final polish by reduced-cost reverse osmosis processes.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Center for Tropical Disease Research and Training | 2.000 | 2.800 | 0.000 | 0.000 |

(U) Program Plans:

- Continue 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|---------|---------|---------|---------|
| EluSys Heteropolymer System | 1.500 | 0.000 | 0.000 | 0.000 |

(U) Program Plans:

- Explored heteropolymer-based drugs in the development of multiple therapeutic candidates for removal and destruction of pathogens, pathogenic proteins, and/or antibodies providing a potential effective treatment for a broad array of diseases.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Hand Held Biosensors for Field Detection of Multiple Bioagents CMIM Palm Pilots | 3.400 | 0.000 | 0.000 | 0.000 |

(U) Program Plans:

- Explored use of hand held biosensors for detection of bioagents.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| New Approaches to Weaponized Infections Organisms | 0.000 | 1.000 | 0.000 | 0.000 |

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Noninvasive Biomodulation | 0.000 | 2.600 | 0.000 | 0.000 |

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------|---------|---------|---------|---------|
| Antimicrobial Research Program | 0.000 | 2.100 | 0.000 | 0.000 |

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------------|---------|---------|---------|---------|
| Bioscience Center for Informatics | 0.000 | 1.000 | 0.000 | 0.000 |

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

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | R-1 ITEM NOMENCLATURE Biological Warfare Defense PE 0602383E, R-1 # 14 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|---------|---------|---------|---------|
| Chemically Programmable Immunity | 0.000 | 1.000 | 0.000 | 0.000 |

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

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

| | <u>FY 2004</u> | <u>FY 2005</u> | <u>FY 2006</u> | <u>FY 2007</u> |
|----------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Previous President's Budget | 149.105 | 147.533 | 147.975 | 146.604 |
| Current Budget | 141.921 | 159.567 | 145.354 | 144.050 |
| Total Adjustments | -7.184 | 12.034 | -2.621 | -2.554 |
| Congressional program reductions | 0.000 | -1.466 | | |
| Congressional increases | 0.000 | 13.500 | | |
| Reprogrammings | -1.000 | 0.000 | | |
| SBIR/STTR transfer | -6.184 | 0.000 | | |

- (U) **Change Summary Explanation:**
- FY 2004 Decrease reflects SBIR transfer and below threshold reprogramming.
- FY 2005 Increase reflects eight congressional adds for various biological warfare efforts offset by congressional undistributed reductions.
- FY 2006 - 2007 Decrease reflects minor program repricing.

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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 Tactical Technology PE 0602702E, R-1 # 16 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 247.405 | 327.825 | 361.562 | 418.818 | 455.831 | 483.565 | 494.565 | 499.565 |
| Naval Warfare Technology TT-03 | 41.666 | 52.313 | 47.871 | 52.944 | 54.943 | 55.190 | 60.190 | 60.190 |
| Advanced Land Systems Technology TT-04 | 41.269 | 69.997 | 77.191 | 82.249 | 102.552 | 124.609 | 129.109 | 129.109 |
| Advanced Tactical Technology TT-06 | 96.031 | 101.387 | 95.849 | 118.502 | 125.074 | 125.256 | 125.256 | 125.256 |
| Aeronautics Technology TT-07 | 26.509 | 49.660 | 78.290 | 94.808 | 95.343 | 95.252 | 95.752 | 95.752 |
| Advanced Logistics Technology TT-10 | 18.203 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Network Centric Enabling Technology TT-13 | 23.727 | 54.468 | 62.361 | 70.315 | 77.919 | 83.258 | 84.258 | 89.258 |

(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, Aeronautics 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. 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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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, R-1 # 16 | |

(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. Networking Extreme Environments 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 an imaging array system that can identify the presence of people inside of buildings and technology capable of stand-off detection of explosive compounds. 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.

(U) The Advanced Tactical Technology project is exploring the application of compact and solid state lasers; high performance computational algorithms to enhance performance of radars, sensors, communications, electronic warfare, and target recognition and tracking systems; 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 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.

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|--|----------------|----------------|---------------|---------------|
| (U) <u>Program Change Summary:</u> <i>(In Millions)</i> | FY 2004 | FY 2005 | FY2006 | FY2007 |
| Previous President's Budget | 247.405 | 339.175 | 354.525 | 351.751 |
| Current Budget | 247.405 | 327.825 | 361.562 | 418.818 |
| Total Adjustment | 0.000 | -11.350 | 7.037 | 67.067 |
| | | | | |
| Congressional program reductions | 0.000 | -23.200 | | |
| Congressional increases | 0.000 | 11.850 | | |
| Reprogrammings | 0.000 | 0.000 | | |
| SBIR/STTR transfer | 0.000 | 0.000 | | |

(U) Change Summary Explanation:

FY 2005 Decrease reflects congressional program reductions to Novel Sensors, Laser Star, Combat Zones that See, and undistributed reductions offset by congressional adds for National Cyber Security Center, Tactical Awareness for Friend or Foe, CEROS and NASEC.

FY 2006 - 2007 Increase reflects additional funding in the TT-07 project for the Reusable Hypersonics, Walrus, and UAV programs and expansion of naval warfare programs in the TT-03 project.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | DATE February 2005 | | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | | | R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-03 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Naval Warfare Technology TT-03 | 41.666 | 52.313 | 47.871 | 52.944 | 54.943 | 55.190 | 60.190 | 60.190 |

(U) Mission Description:

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 2004 | FY 2005 | FY 2006 | FY 2007 |
| Friction Drag Reduction | 3.605 | 9.250 | 13.009 | 16.899 |

(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 and submersibles that far exceed the cost of implementation. Such a capability would result in dramatic decreases in fuel usage, increases in payload fraction and burst speed, and substantial enhancements in vehicle range and endurance. To date, the program has developed the capability to predict from first-principles how turbulence is modified by the presence of polymers and microbubbles. These first-principles models were validated with small-scale physical experiments. This predictive capability will be extended to large scales, so that optimum implementation at ship-relevant scales may be identified. 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 or quarter-scale submarine).

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(U) This program also examined the potential of Lorentz Force Turbulence Control (LFTC), an approach to reduce hydrodynamic drag by the generation of electromagnetic forces. Laboratory tests have demonstrated effective underwater drag reduction, but the energy requirements are very high.

(U) Program Plans:

- Analysis of LFTC data and final report completed.
- Developed a multi-scale modeling capability that will incorporate the physics learned at small scales into large-scale engineering codes for use as reliably predictive design tools.
- Finalized buoyancy test vehicle modeling design and efficiency.
- Developed a preliminary test plan for full-scale buoyancy test vehicle experiment.
- Conducted a full-scale buoyancy test vehicle experiment to provide high-quality data at large scales in order to validate the models.
- Develop an air cavity design tool that calculates a hull form for specified pressure distributions.
- Perform modeling trade-off analysis to determine optimal hull forms supporting air cavity formation at design speed.
- Conduct tests to determine drag reduction achieved.
- Study physics-based hydrodynamic codes to accurately represent the critical features needed to predict design parameters for small craft.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Surface Warfare Automated Shiphandling (SWASH) | 0.000 | 5.400 | 4.914 | 7.822 |

(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

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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.

- (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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Hypersonics Flight Demonstration (HyFly) | 22.099 | 19.615 | 11.882 | 3.078 |

(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 a vehicle range of 600 nautical miles with a block speed of 4,400 feet per sec, maximum sustainable cruise speed in excess of Mach 6, and the ability to deploy a simulated or surrogate submunition. Technical challenges include the scramjet propulsion system, lightweight, high-temperature materials for both aerodynamic and propulsion structures, and guidance and control in the hypersonic flight regime. Recently demonstrated performance in ground testing of the dual combustion ramjet engine coupled with advances in high temperature, lightweight aerospace materials are enabling technologies for this program. The program will pursue a dual approach. The core program will focus on development and demonstration of capabilities requisite for 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 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:

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| High Efficiency Distributed Lighting (HEDLight) | 5.988 | 6.200 | 2.354 | 0.000 |

(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 luminaires; 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Center of Excellence for Research in Ocean Sciences (CEROS) | 7.000 | 7.000 | 0.000 | 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 monitored progress of ocean related technologies of high interest to the DoD.
 - Transition appropriate products to military use.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Acoustic Arrays for Torpedo Defense (formerly Electric Curtain) | 2.974 | 4.848 | 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 wake homing 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 wake homing torpedo at tactically significant ranges.

- (U) Program Plans:
- Conduct non-linear pressure pulse propagation modeling and assess projected system performance.
 - Design, develop and test transducer module.
 - Incorporate ship wake effects into the pressure pulse propagation model.
 - Design, develop, and test ¼-scale transducer array.
 - Conduct ¼ scale system testing.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------|---------|---------|---------|---------|
| Ribbon Fin Propulsion | 0.000 | 0.000 | 3.034 | 6.683 |

(U) The Ribbon Fin Propulsion program will develop a novel underwater propulsion technology for Unmanned Underwater Vehicles (UUV) and other underwater platforms that require high maneuverability at low velocities. It is believed that 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 to maximize thrust, 2) determining the structure of the fluid flow imparted by the ribbon fin, 3) determining how to implement a flexible

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ribbon structure with sufficient power and controllability to be useful, and 4) 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------------|---------|---------|---------|---------|
| Riverine Crawler Underwater Vehicle | 0.000 | 0.000 | 3.420 | 5.261 |

(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. Novel means of navigation, propulsion and sensing will be required to operate autonomously in such environments. Port security is a key area of worldwide concern, especially when one considers the tremendous volume of goods that traverse through major ports located around the world. Monitoring traffic flow and obtaining vessel identification information, as well as information on shore activities, would be of considerable value.

(U) A little-explored means of operating in a riverine environment is by an unmanned submerged craft. 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:
- Conduct Phase I analysis and select up to two teams for Phase II development.
 - 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Small Craft Advanced Hydrodynamic Design | 0.000 | 0.000 | 5.498 | 11.201 |

(U) Based upon the results of the Friction Drag Reduction program (budgeted in this PE/Project) and other DARPA efforts, the Small Craft Advanced Hydrodynamic Design effort will develop a new capability in predicting small boat hydrodynamics, including small scale phenomena in highly dynamic sea-states, for boats used for high speed patrol, area defense or personnel insertion. The objective of the effort is to demonstrate the capability to produce a physics-based small craft design with prescribed performance parameters. Improved design capability for small craft is critical for the development of stealthy high-speed special warfare craft and for improving the physical impact on crew members during high speed operations.

(U) Program Plans:

- Complete physics-based hydrodynamic codes to accurately represent the critical features needed to predict design parameters for small craft.
- Conduct performance prediction in dynamic environments such as high waves and currents.
- Develop and build a prototype small craft design that exhibits the desired parameters.
- Demonstrate at-sea performance in variable sea conditions.

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

| | | | | |
|---|---------|---------|---------|---------|
| Hypersonics Flight Demonstration | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| PE 0602114N, PE 0603114N, PE 0603123N, Navy, Office of Naval Research | 20.000 | 15.000 | 11.300 | 2.200 |

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Advanced Land Systems Technology TT-04 | 41.269 | 69.997 | 77.191 | 82.249 | 102.552 | 124.609 | 129.109 | 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); Stimulated Isomer Energy Release (SIER); MAgneto Hydrodynamic Explosives Munition (MAHEM); Compact Military Engines; Crosshairs, Vertical Infiltration, Persistent Extraction Robot (VIPER), Improved Explosives, Agile Interceptor, Counter Improvised Explosives Laboratory (CIEL) and the National Cyber Security Center.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|------------------------------------|---------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Novel Sensors for Force Protection | 9.919 | 10.910 | 13.459 | 18.352 |

(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, the Explosives Detection Project, and congressionally added funds for Tactical Awareness for Friend or Foe.

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(U) The objective of the Unique Signature Detection Project 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 Project 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 Urban Vision Project will develop the technology and systems to provide the warfighter with an advanced in-depth view of the distribution and location of dielectric bodies that resemble those of enemy dismounted troops or combatants within a building in an urban area. Each node of the array carries a suite of low-power transmitters and receivers that act in concert with real-time electromagnetic analysis codes to “peel back” the structure of the building and the disposition of signatures that are indicative of enemy dismounted troops or combatants within.

(U) The Explosives Detection Project seeks to develop technologies capable of standoff (non-contact) detection of explosive compounds. Of particular importance are high throughput applications, such as military checkpoints, where an extremely low false alarm rate is required. Rather than promoting a single, particular technology, this program will develop a systematic framework of understanding for both the target and background signals. With such an understanding, concepts such as sensor fusion and the optimum setting of thresholds can be properly optimized. In this manner, a system of sensors can be developed that has reliable detection capabilities in both laboratory and field environments. This capability will greatly reduce the threat of suicide bombing, Improvised Explosive Devices (IEDs), and similar tactics faced by troops in the field.

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(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.
 - 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 Unmanned Aerial Vehicles (UAV) array multi-static dielectric tomography imaging system.
- Explosives Detection.
 - Examine current and emerging technology.
 - Develop an understanding of background conditions in varying environments.
 - Design detectors capable of reliable, low false alarm, stand-off explosives detection.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|---------|---------|---------|---------|
| Dynamic Optical Tags (DOTS) | 5.947 | 8.819 | 9.905 | 7.794 |

(U) Based on the technical successes and demonstrated operational relevance of DARPA's now completed Optical Tags program, the Dynamic Optical Tags program seeks to create new tagging, tracking, and location capabilities for U.S. Forces. This program will develop optical tagging and interrogation technologies that will enable small environmentally robust, retro reflector-based tags 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 or monitoring tactical areas for disturbance from personnel and vehicles. The identification tags also will be capable of providing persistent two-way communications for both tactical and logistics operations.

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------|---------|---------|---------|---------|
| Guided Projectiles | 10.909 | 16.477 | 20.572 | 17.547 |

(U) The Guided Projectiles program is developing and demonstrating highly maneuverable gun-launched projectiles, and associated launch system, and fire control, for point defense against highly maneuverable targets, such as anti-ship cruise missiles, ground-to-air and ground-to-ground threats. This program will also 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, ad-hoc

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networking, sensing and propellants/explosives to demonstrate significant leaps in combat capability. These technologies 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.

(U) The program will also develop small aperture, geolocation capability for a new-class of anti-radiation weaponry. This program will enable a suite of weapons that home on RF energy emitted by enemy forces to include ground-to-ground, air-to-ground, and ground-to-air weapons all using similar RF sensor guidance technology. The result of this effort will 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 will focus on providing an RF homing guidance and warhead package that is 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 defense 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:

- Develop, model and validate supersonic flight control technologies.
- Conduct preliminary development and evaluation of key subsystem technologies.
- Perform initial flight demonstrations and target acquisition demonstrations.
- Fabricate and test critical subsystems for projectile maneuvering, guidance and data transmission.
- Conduct detailed design and feasibility tests of key fire control, lethality, flight control and launch components.
- 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 mortar high explosive round.

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- 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.
- Develop small, moving aperture geolocation techniques, such as tomographic geolocation.
- Investigate techniques for the reduction of channel mismatch errors, such as spinning the mortar to remove bias errors.
- Research multipath mitigation and multiple user discrimination techniques, such as subspace tracking techniques.
- Develop mortar-sized electronics and guidance package.
- Demonstrate tube launch of 81mm RF guided mortar round and field realizable cueing system in conjunction with transition partner.
- Initial design of mortar mounted RF seeker and mortar control system.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Networking Extreme Environments (NetEx) | 5.858 | 8.425 | 4.978 | 3.958 |

(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.
- Develop 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.

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- Develop ad-hoc networking and multiple access protocols to take advantage of the unique properties of UWB.
- Integrate UWB communications and sensors systems into an interoperating net.
- Conduct experiments on the integration of UWB into an operating network.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Stimulated Isomer Energy Release (SIER) | 3.000 | 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 is to develop a technique to control the release of this energy. The program will demonstrate that as much energy can be released as is used to initiate the reaction (a breakeven experiment).

(U) Program Plans:

- Determine 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.
- Identify a hafnium isomer production process that is affordable and cost effective.
- Develop a physics approach to a chain reaction for the hafnium isomer.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| MAgneto Hydrodynamic Explosive Munition (MAHEM) | 0.000 | 4.200 | 4.880 | 4.765 |

(U) The MAgnetoHydrodynamic 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 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

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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:

- Refine magnetohydrodynamic models of MAHEM behavior.
- Conduct capacitor-driven liner experiments to validate models.
- Complete single and multiple-liner CMFG and MAHEM concept designs.
- Develop and conduct experiment demonstration of CMFG and CMFG-driven MAHEM.
- Develop MOA with transition partners, demonstrating MAHEM variants tailored to their mission-specific requirements.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------|---------|---------|---------|---------|
| Compact Military Engines | 2.000 | 6.066 | 2.210 | 1.324 |

(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 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.

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- (U) Program Plans:
- Complete 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------|---------|---------|---------|---------|
| Crosshairs | 1.636 | 4.000 | 6.000 | 9.500 |

(U) This program will develop methods and equipment to enable blue-team forces to detect, locate, and engage shooters and defeat Rocket Propelled Grenades (RPGs), Anti-Tank Guided Missiles (ATGMs), etc. in urban environments. Location will be made with sufficient timeliness for effective counteraction and shooter elimination. This will be achieved with minimal exposure of blue-team forces to further attack. A combination of techniques will be used to achieve these goals. Technologies may include acoustic sensors to determine bullet shooter locations and high-speed IR imaging or radar to determine RPG trajectories and backtrack to shooter origin. 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. 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 platoon or squadrons while stationary. Techniques for supporting detection and false-alarm rate mitigation will be considered, including acoustic detection, optical, radar and sniper scope detection. It is envisioned that the system will provide a significantly improved capability to detect and engage snipers 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 degrees 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.

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- Analyze data and integrate sensors and response system with appropriate vehicle mounted counter-measures.
- Assess utility for dismounts.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Vertical Infiltration, Persistent Extraction Robot (VIPER) | 2.000 | 5.100 | 0.000 | 0.000 |

(U) This program will apply concepts from the Novel Sensors program to the development of technologies to enable a robotic platform with a small body diameter and three-dimensional mobility. System challenges to the development of a high-degree-of-freedom robot include: power generation, management and storage; locomotion; terrain and situational awareness; navigation and control; health and status monitoring; and position and configuration management. The program will also evaluate design approaches and concepts of operation for implementation and utilization of such a robotic platform.

(U) Program Plans:

- Perform a risk reduction and feasibility demonstration phase of the basic platform.
- Develop the integrated robotic system concept and multiple degree-of-freedom operator control software.
- Complete component testing to characterize system performance.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------|---------|---------|---------|---------|
| Improved Explosives | 0.000 | 0.000 | 5.398 | 7.260 |

(U) Drawing upon work performed in the Guided Projectiles program, the Improved Explosives program seeks to develop more powerful explosives for existing U.S. munitions. Such explosives 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, as a result of the development of explosives with better energy transfer. The goal of the program is to develop high explosives systems that deliver three to five times more power (pound-per-pound) than conventional systems that use

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TNT or Composition B. The power of the explosive will be measured in peak pressure and brisance. The intent is to use the improved explosives in small projectiles that are easily moved about the battlefield. Initially, this program will focus on developing a lightweight wall-breaching rocket system that will allow ground troops to quickly deliver, with one shot, an explosive system to make a large hole in walls and buildings so they can enter unexpectedly.

- (U) Program Plans:
- Develop shaped charge explosives and associated technologies that will yield high energy transfers, warhead-to-target.
 - Develop methods to extend the service life of small diameter anti-tank munitions (e.g., the current M72 LAW and AT4) so that these munitions can be upgraded with improved explosives rather than develop new munitions.
 - Develop new high-hydrogen explosives.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------|---------|---------|---------|---------|
| Agile Interceptor | 0.000 | 0.000 | 8.289 | 10.249 |

(U) The Agile Interceptor, an out-growth of the Guided Projectiles program, will develop and demonstrate a projectile system to protect limited areas 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. The program will be a multi-phase program 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.
 - Initiate second phase to improve selected technologies and integrate them into the overall interceptor system.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Counter Improvised Explosives Laboratories (CIEL) | 0.000 | 1.000 | 1.500 | 1.500 |

(U) This program is an outgrowth of the work performed in this project under the Novel Sensors for Force Protection, Explosives Detection Project. 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 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------|---------|---------|---------|---------|
| National Cyber Security Center | 0.000 | 1.000 | 0.000 | 0.000 |

(U) Future weapon systems for the tactical warfighter will increasingly rely upon the ability to transmit, receive, store and manipulate information. The security of this information is paramount and the techniques to accomplish this will need 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:

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

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(U) Other Program Funding Summary Cost:

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Advanced Tactical Technology TT-06 | 96.031 | 101.387 | 95.849 | 118.502 | 125.074 | 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; (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 2004 | FY 2005 | FY 2006 | FY 2007 |
| High Power Fiber Lasers | 11.787 | 11.270 | 10.606 | 9.000 |

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| High Powered Femto Second Laser Diodes | 3.270 | 3.151 | 4.000 | 5.000 |

(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.
 - Develop and demonstrate technology for portable (backpack and small vehicle-mounted), efficient high-peak power, ultra-short pulse laser systems, enabling a range of DoD applications requiring mobile, high power laser sources.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Super High Efficiency Diode Sources (SHEDS) | 9.916 | 9.188 | 4.288 | 3.000 |

(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 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/cm² per diode stack operating continuously.
- Achieve a peak power of 2000W/cm² 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| High Energy Liquid Laser Area Defense System (HELLADS) | 11.948 | 20.841 | 20.000 | 20.000 |

(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 UAVs and will significantly increase engagement ranges compared to ground-based systems. This program initiative will investigate and validate a revolutionary laser design that enables a

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lightweight HEL weapon system. HELLADS will design, fabricate and test a prototype laser. A laboratory demonstration of key performance parameters will be performed, followed by the fabrication and testing of a subscale HEL laser. Once key weapon system parameters have been demonstrated, a full-scale 150 kW HEL weapon system will be fabricated and demonstrated. Finally, the 150 kW HEL will be integrated into a surrogate aircraft and key performance parameters will be demonstrated.

- (U) Program Plans:
- Conduct key technology demonstrations of resonator stability, laser gain, and system thermal performance.
 - Develop and test a 15 kW sub-scale HEL system.
 - Complete detailed design and initiate construction of 150 kW laser weapon system.
 - Demonstrate performance of a 150 kW HEL system in a ground test.
 - Integrate HEL system into surrogate aircraft.
 - Demonstrate performance of a 150 kW HEL system in captive flight test.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------|---------|---------|---------|---------|
| Laser Star | 7.677 | 2.885 | 2.800 | 2.000 |

(U) The Laser Star program will investigate technologies and techniques for improving laser guide star generation for adaptive optics atmospheric compensation of laser propagation. Current technology 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 are being developed to overcome these shortfalls.

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- (U) Program Plans:
- Complete concept design.
 - Develop experiment design and procure long lead items.
 - Conduct experiment.
 - Analyze data and integrate with atmospheric compensation programs.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Coherent Communications, Imaging and Targeting | 8.872 | 8.020 | 6.200 | 5.725 |

(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 aberrating 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 in all weather conditions. New capabilities achieved by advances in SLMs allow for seamless transfer or hand-off of digital radar target acquisition data. 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

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waves allows for significant improvement in data carrying capacity. The program will also develop system level architectures for secure free space optical communication networks.

(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.
- Concept development of target acquisition and hand-off to SLM arrays.
- Develop concept for unambiguous resolution and detection of OAM states.
- Conduct computer modeling of OAM modification.
- Design laser transmitter and receivers.
- Develop orthogonal code.
- Develop prototype system with high-speed parallel electronics and demonstrate ground to space communication links and aberration-free imaging.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| High Performance Algorithm Development/Virtual Electromagnetic Test Range | 13.155 | 13.409 | 11.471 | 17.500 |

(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.
 - Explore innovative mathematical representations of digital data and systems that provide improved efficiency and robustness against error and uncertainty compared to current representations.
 - 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------------|---------|---------|---------|---------|
| Integrated Sensing and Processing | 8.697 | 8.165 | 5.000 | 7.000 |

(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.
- Develop and demonstrate multiplex sensing, feature extraction and three-dimensional imaging capability in passive interferometric sensors.
- Develop and demonstrate spatio-spectral feature extraction and four-dimensional (three spatial, one spectral) reconstructions in passive interferometric sensors.
- 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.

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- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------------|---------|---------|---------|---------|
| Mission Specific Processing (MSP) | 2.589 | 2.563 | 0.000 | 0.000 |

(U) The Mission Specific Processing (MSP) program extends Adaptive Computing Systems (ACS) technologies to support the design of highly optimized embedded processors that are required in the most severely constrained DoD applications. ACS developed new approaches to the design of computer hardware that incorporated dynamic configuration capabilities. 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 ASIC designs by incorporating full-custom design optimizations into standard libraries. The MSP design flow methodology will be made available to all DoD contractors thru the circuit design center, 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 AFRL to enable potential Air Force system insertion.

(U) Program Plans:

- Conduct simulation and benchmarking of initial custom design techniques in the context of mission specific signal processing requirements.
- Develop detailed system architecture of wideband adaptive radar/electronic intelligence-/seeker receiver enabled by MSP method.
- Develop a wideband adaptive radar receiver based on MSP custom cell libraries and modules.
- Demonstrate a ten-fold performance improvement in custom radar signal processing chips.
- Complete library of key digital signal processing function kernels and supporting tool augmentations.
- Complete development and demonstration of space-time adaptive processor for seeker-receiver.
- Conducts first pass evaluation of semi -custom, full scale chip in a space-time adaptive receiver testbed.
- Demonstrate full scale ASIC development using MSP architectures and techniques focusing on MSP design methodologies that reduce design time requirements as compared with full custom.

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- Complete a demonstration that addresses system level issues and quantifies the increased performance relative to standard cell ASIC designs.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------|---------|---------|---------|---------|
| Training Superiority | 15.736 | 15.029 | 15.542 | 25.717 |

(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.
- 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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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Language and Speech Exploitation of Resources Advanced Concept Technology Demo | 0.700 | 0.132 | 0.132 | 0.000 |

(U) DARPA’s Compact Aids for Speech Translation (CAST) program is developing 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:

- Refined the two-way translator capabilities for testing in military utility assessments (MUAs).
- Developed a translator in Arabic dialect for which substantial annotated speech data was available.
- Integrated component technologies including:
 - Speech recognition in English and Arabic.
 - Speech playback in Arabic and English.
 - Information extraction and translation from Arabic to English.
- Ported translator to a second critical language (e.g., Vietnamese, Thai), for which little annotated speech data is now available.
- Installed translator on small, readily available platforms (e.g., laptops, handhelds).
- Test and evaluate language technology in the service labs.
- Transition the translator technology to the ACTD for MUAs.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------|---------|---------|---------|---------|
| Air Laser | 0.000 | 2.424 | 3.344 | 6.270 |

(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-class HEL which combines the advantages of chemical and solid state

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lasers and minimizes the disadvantages: it operates in the eye-safe wavelength regime; it uses liquid air as the gain medium and as the diode array coolant, resulting in the reduction or elimination of a separate thermal control system; the use of efficient, high energy density diode pump sources, results 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 4 kW intra-cavity laser design.
 - Develop and demonstrate 20 kW laser design.
 - Develop 100 kW laser design.
 - Develop kilowatt-class red diodes.
 - Develop high-power mirror coatings for this wavelength.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Architecture for Diode High Energy Laser Systems | 0.000 | 0.000 | 4.000 | 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 decrease 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.

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- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------|---------|---------|---------|---------|
| Slingatron | 0.000 | 0.000 | 3.000 | 4.000 |

(U) The Slingatron program will use modern engineering and physics concepts to accelerate masses to extremely high velocities. This mechanical mass acceleration concept, based on using centripetal body forces, is fundamentally different from electro-magnetic accelerators and hence avoids the limitations of those machines. Initial studies have demonstrated the fundamental feasibility of the Slingatron concept. This program will explore the concept's bounding limits and seek to develop uses for the technology within those limits. Included in this program will be studies of the key technologies that will allow the accelerator to achieve very high projectile energies.

- (U) Program Plans:
- Conduct feasibility analysis and design studies; fabricate experimental launchers.
 - Demonstrate mass launchers that range in capabilities over three to four orders of magnitude.
 - Demonstrate mass velocities on the order of several km/s and perhaps higher than 10km/s.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------------|---------|---------|---------|---------|
| Photonic High Power Microwave System | 0.000 | 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.

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------|---------|---------|---------|---------|
| Rapid Checkpoint Screening | 1.481 | 4.310 | 4.466 | 3.290 |

(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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------|---------|---------|---------|---------|
| Water Rocket | 0.203 | 0.000 | 0.000 | 0.000 |

(U) The Water Rocket program supported research and development of a robust concept for space power and propulsion supported by water as a replenishable propellant and fuel. Water is an inexpensive and easily handled propellant. A regenerative fuel cell system, enabled by emerging new technologies, was developed and demonstrated. The regenerative fuel cell would: 1) convert water to hydrogen and oxygen for use in thrusters, and 2) generate electricity while converting some of the hydrogen and oxygen back to water, thereby replacing the heavy batteries routinely used in satellites to supply electric power during nighttime. As a result of this program, future spacecraft will be more easily maneuvered, moved into higher orbits, and refueled to accomplish advanced missions.

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- (U) Program Plans:
 - Performed critical technology demonstrations and analysis of the system for the regenerative fuel cell and other developmental components.
 - Designed, fabricated, and tested a brassboard regenerative fuel cell system demonstrating performance and endurance.

- (U) **Other Program Funding Summary Cost:**
 - Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Aeronautics Technology TT-07 | 26.509 | 49.660 | 78.290 | 94.808 | 95.343 | 95.252 | 95.752 | 95.752 |

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
| Micro Adaptive Flow Control (MAFC) | 11.422 | 9.736 | 4.015 | 3.300 |

(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.
- Design and integrate SCORPION full-scale control system.
- Configure and execute Phase III full-scale technology demonstrations.
- Conduct analysis of vortex interactions at a level necessary to achieve useful performance and aircraft control in close proximity.
- Evaluate advanced composite manufacturing techniques for air vehicles and flow control.
- Develop SSMAV system level requirements, control authority, navigation accuracy, and emplacement techniques, particularly for applications in urban environments.
- Conduct detailed simulation studies to determine enhanced range and precision capability with chemical thruster jets.
- Conduct experimental wind tunnel tests with candidate fixed wing/rotary wing micro air vehicle (2 to 5 inches in size).
- Conduct experimental wind tunnel tests with integrated chemical thruster jets to determine control authority improvement and aerodynamic performance, i.e. stall characteristics of vehicles.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------------|---------|---------|---------|---------|
| Small Scale Propulsion Systems (SSPS) | 9.087 | 7.864 | 4.385 | 4.354 |

(U) Concepts for a new, small scale class of propulsion systems will be developed in the size range from 0.5 cm to 7.0 cm in diameter, with thrust levels from 10g to 10kg. They will enable future development of a new generation of very small weapons and military platforms including micro air vehicles, unmanned combat air vehicles, missiles and space launch vehicles. Radical new capabilities to be explored range from shirt-button-sized gas turbine and rocket engines to 7 cm scale gas turbine and pulse detonation engines. Engines may be explored at larger scale to prove feasibility. Examples of new mission capabilities may include delivery of very small (200g) satellites to low earth orbit, extended range small-scale precision munitions, and lightweight, long endurance miniature reconnaissance vehicles. These small-scale munitions would complement emerging unmanned vehicle systems and greatly increase mission capabilities by simultaneously increasing loadout, range and precision. In addition, the program will explore the feasibility of using miniature pulse detonation engines (MPDEs) to acoustically and thermally (infrared) emulate vehicle signatures.

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- (U) Program Plans:
- Demonstrated the critical components of a liquid-fueled micro-rocket with turbopumps operating with 1.5 kg thrust.
 - Achieved diesel fuel operation of a novel crankless internal combustion engine.
 - Demonstrated initial operation of a small diesel-fueled turbojet engine with a 20:1 thrust to weight ratio on.
 - 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 multifunctional structure plus battery for micro air vehicle (MAV) wings that yield three times more duration than with traditional wing structures and conventional batteries.
 - Investigate compatibility of optical flow and uncooled IR approaches with multifunctional structures to enhance surveillance capability.
 - Transition micro air vehicle to military applications.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------|---------|---------|---------|---------|
| Peregrine / UAV Killer | 0.000 | 1.410 | 3.200 | 6.146 |

(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.

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- Demonstrate aircraft performance and kill capability.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------|---------|---------|---------|---------|
| Walrus | 6.000 | 10.000 | 20.000 | 30.000 |

(U) The Walrus program will develop and evaluate a very large airlift vehicle concept that is designed to control 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 will generate lift through a combination of aerodynamics, thrust vectoring and gas buoyancy generation and management and for much of the time, it will fly heavier than air. The program will develop an operational vehicle concept and will conduct risk reduction demonstrations on a Walrus Advanced Technology Demonstration (ATD) air vehicle. The ATD vehicle will demonstrate scalable aircraft technology, is anticipated to achieve comparable C-130 airlift capability, and will explore, develop, and demonstrate the system concepts of operation. The Walrus objective vehicle will have a primary mission to deploy composite loads of personnel and equipment (for example, the components of a Unit of Action) ready to fight as they disembark from the aircraft within 6 hours after landing. Walrus will operate without significant infrastructure and from unimproved landing sites, ostensibly flat but over rough ground to tolerate 5 feet high obstacles. It will carry a useful payload >500 tons over global distances (12,000 nm in less than 7 days) at a competitive cost. Additionally, Walrus will be capable of performing theater lift, support of Sea Basing, and persistence missions to meet a range of multi-agency needs. Advanced breakthrough technologies will be investigated in the first phase to support the development of lift and buoyancy concepts. The program's first phase will include system studies and development of a notional concept of the objective vehicle. Based on these studies and concept viability, the competitive second phase will lead to the development of an objective air vehicle design and building and initial flight test of the ATD vehicle. Outyear funding is budgeted in PE 0603286E, Project AIR-01 to continue the program past Phase I.

(U) Program Plans:

- Define and develop a notional objective air vehicle concept having a payload capability circa 500 tons.
- Establish the feasibility of breakthrough technologies.
- Develop air vehicle design concepts that will validate the objective air vehicle concept.
- Perform conceptual design and trade studies of air vehicle variants for a variety of mission roles, including study of technology risk reduction, architecture, survivability, and vehicle conservation.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| High Speed / Hypersonic Reusable Demonstration | 0.000 | 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+.

(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.

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- Perform component integration.
- Conduct integrated engine ground testing.
- SED
 - Develop flight vehicle design.
 - Conduct freejet engine testing.
 - Fabricate flight demo vehicle.
 - Conduct flight testing.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Helicopter Quieting (formerly Helicopter Rotor Blade Quieting) | 0.000 | 5.650 | 6.290 | 8.552 |

(U) Studies and performance results from current U.S. military operational systems, as well as other DARPA programs in this project, have shown that it is vital to increase the survivability and lethality of U.S. helicopters by reducing their acoustic signature, thereby making 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 approaches rely on an iterative cycle of analysis and model wind tunnel tests (time consuming and costly) or go 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. Recent advances in computational fluid dynamics (CFD) will be leveraged 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.
 - Validate models using experimental data.

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- Use the tools to design new blades that yield a significant reduction in low-frequency, in-plane signature.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------|---------|---------|---------|---------|
| Nano-Flapping Air Vehicles | 0.000 | 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 2 inch wingspan and gross takeoff weight of approximately 10 grams or less. Operations in the urban terrain require sensors that can navigate in difficult terrain and to 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 technology 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. This would make possible the use of vehicles, which could be camouflaged, or blend into the surrounding landscape, enabling in theater disposal and preventing 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------|---------|---------|---------|---------|
| Flare Aero Structures | 0.000 | 0.000 | 2.100 | 5.800 |

(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 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 such as the FCS Class III 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------|---------|---------|---------|---------|
| Macaw | 0.000 | 0.000 | 6.000 | 9.000 |

(U) This program is an outgrowth of the Small Scale Propulsion Systems (SSPS) program. The goal of the Macaw program is to develop a helicopter emulator carried on a small UAV. The system would use miniature pulse detonation engine (MPDE) technology to 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, determine their location, and relay the information back to the operator. 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.

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- (U) Program Plans:
- Model the acoustic and thermal (IR) signatures of common helicopters.
 - Develop MPDEs 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.

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

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Network Centric Enabling Technology TT-13 | 23.727 | 54.468 | 62.361 | 70.315 | 77.919 | 83.258 | 84.258 | 89.258 |

(U) Mission Description:

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------------|---------|---------|---------|---------|
| Network Embedded Systems Technology | 11.318 | 11.255 | 7.000 | 4.000 |

(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 sensor networks consisting of elementary nodes 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 a few tens of simple computing nodes arrayed in a network in an ad hoc manner to several tens of thousands of nodes. NEST produces reusable software libraries and design tools that simplify the design task for those applications.

(U) Program Plans:

- Design deterministic and probabilistic methods for self-stabilizing protocols for lightweight coordination services, such as global clock synchronization and/or sensor localization.
- Develop design tools for the customization of coordination-services to specific applications based on requirements and platform characteristics.
- Develop formal modeling and verification techniques for coordination and integration.
- Conduct field experiments and demonstrations of NEST technology in a variety of sensor network monitoring and tracking applications of relevance to the Special Forces, the Marines and the Army.
- Demonstrate real-time synthesis of schedules (e.g., actuator firing sequences) and services (e.g., localization, route planning) using phase transition-aware constraint solvers.
- 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------|---------|---------|---------|---------|
| Combat Zones That See (CZTS) | 0.000 | 4.213 | 7.436 | 8.875 |

(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 system deployable from ground positions and unmanned aerial vehicles.

(U) Program Plans:

- Develop, install and evaluate a force protection prototype, on an overseas military base, that employs approximately 30 cameras.
- Demonstrate sustained tracking of individual vehicles using sensors whose fields-of-view do not overlap.
- 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 MOUT-configured prototype using approximately 100 rapidly deployed cameras.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|---------|---------|---------|---------|
| Automated Battle Management | 6.332 | 14.800 | 13.723 | 15.459 |

(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 Mission Driven Control of Autonomous Robotic Systems (MDCARS) program will develop autonomous control methods to cause distributed platforms to self-organize and distribute tasks through judicious transactions conveyed over a shared communications network. Techniques to permit rapid insertion of new functional elements (such as, new platforms, sensors, control stations, visualization tools, algorithms, and databases) into robotic system networks will be explored. MDCARS supports explicit publication of data models and control strategies used by sensors, algorithms, tools, and databases and references appropriate knowledge bases to define transformations between different data models. Products will be integrated via semi-automatic tools to accelerate system and information integration. This effort permits rapid adaptation of robotic systems behavior to changes in the real-time military situation. The program accelerates configuration and integration of robotic systems at field sites, enabling rapid technical upgrade, improving interaction with coalition partners and system tailoring to new environments. Finally, this effort allows complex robotic systems to be rapidly assembled from discrete pretested components and tailored robotic systems to be assembled for particular tasks.
- 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

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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:

- Mission Driven Control of Autonomous Robotic Systems.
 - Interact with visionary military experts; identify combined arms scenarios where highly robotic systems offer tactical advantages.
 - Construct a simulation-based testbed to mimic the kinematics, sensors, and logistics of a representative robotic force.
 - Procure a set of distributed control technologies, based on distinct technical approaches.
 - Implement each technology as a closed-loop controller attached to the simulation-based testbed.
 - Implement testbed results and downselect to the two best approaches.
 - Establish a hardware-in-the-loop test facility at a secure military installation, including robotic platforms and communications nets.
 - Select the most advanced control technologies in terms of speed, flexibility, and robustness.
 - Implement quarterly exercises of the control schemes in the test facility.
 - Coordinate with transition partner(s) final demonstrations as part in a series of Service exercises.
- Organic Sensor Exploitation Networks (OSEN).
 - Define representative sensor mixes and operational scenarios.
 - Perform analytical trade studies to generate representative sensor network components and tactics.
 - 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------|---------|---------|---------|---------|
| Eyes-On System | 1.132 | 5.350 | 0.000 | 0.000 |

(U) The goal of the Eyes-On (EyO) System program is to develop 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 will also allow 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 is developing 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 is adapting existing sensor and platform designs and fabricating 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:

- Define system architecture to include command and control requirements.
- Analyze tradeoffs between sensing performance, target location and referencing designs, data rates, and smart processing aboard the small UAV.
- Develop candidate designs at different points of these trade-off curves.
- Simulate each design over a suite of missions and select the design that provides the best overall actionable-ID capability.
- Brassboard and install the selected sensor, signal processing, flight control and data link software on a recoverable test platform.
- Construct and test entire prototype systems.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Urban Warfare Robotic Surveillance (URS) | 0.000 | 2.000 | 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 (EO/IR 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, 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).
- 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------|---------|---------|---------|---------|
| Home Field | 0.000 | 8.500 | 12.652 | 13.989 |

(U) The Home Field program will develop networked video and LADAR processing technology that rapidly and reliably updates a 3D model of an urban area. Urbanscape 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.
- 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.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-13 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Adaptive Reflective Middleware Systems | 4.945 | 5.800 | 6.120 | 5.360 |

(U) The Adaptive and Reflective Middleware Systems (ARMS) program is developing fully 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 quantifiable changes in environmental conditions. ARMS middleware coordinates the exchange of information predictably, scalably, dependably, and securely among remote entities by employing advanced Quality of Service (QoS) capabilities of the underlying network and end systems.

(U) Program Plans:

- Define and prototype adaptive protocols, algorithms, patterns, and technologies.
- Enforce security policies to enhance and support secure global 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.
- Demonstrate the dynamic flexibility and QoS provisioning in the fourth DD(X) TSCE release.
- Define and prototype reflective techniques for synthesizing optimized distributed, real-time, and embedded middleware.
- Develop required information models, algorithms, and technologies; configure customizable, standards-compliant TSCE middleware and applications.
- Develop robust adaptive protocols, algorithms, patterns, and technologies based on standard middleware.
- Demonstrate enforcement of the security policies for global resource allocation, scheduling, and control in the fifth DD(X) TSCE release.
- Develop and demonstrate robust reflective techniques for synthesizing optimized standards-based middleware in the sixth DD(X) TSCE release.

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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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Pre-Conflict Anticipation and Shaping (PCAS) | 0.000 | 0.000 | 4.825 | 6.188 |

(U) The Pre-Conflict Anticipation and Shaping (PCAS) program will develop and integrate a range of preconflict anticipatory and shaping technologies into a unified system for stabilizing operations capabilities through conflict avoidance and strategic surprise prevention. PCAS technologies include computational social science modeling and simulation, scenario generation, evolutionary programming, planning, and multiplayer gaming. When integrated, these technologies 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, then mitigate the impact of that instability. The PCAS system will be tested and validated against current state-of-the-art practices, such as advisory support staff that provide counsel by creating personalized reports about an area of operations using idiosyncratic mental models and research from open source materials. The goal of PCAS' more powerful societal/regional models is an integrated perspective encompassing, in a consistent way, all the dimensions of social change (e.g., geo-political, socio-economic, cultural).

- (U) Program Plans:
- Identify a suite of emerging computational technologies (simulation, game theory, genetic algorithms) that can be applied to predict social change.
 - Select a representative set of geographical regions which are expected to range from stable to highly unstable social dynamics.
 - Obtain a large corpus of data describing the selected regions.
 - Build tools to automatically translate the data corpus into a form usable by the suite of computational techniques.
 - Build prototypes of software tools based on the identified technologies.
 - Conduct regular experiments comparing predictions of the identified techniques with real-world events.
 - Make rugged and operational the remaining techniques to form tools that can be transitioned to joint intelligence centers or the staff at Combatant Commands.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-13 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------|---------|---------|---------|---------|
| Diagnostic Network Economies | 0.000 | 0.000 | 6.000 | 9.000 |

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|---------|---------|---------|---------|
| NASEC Through Wall Radar Imaging | 0.000 | 2.550 | 0.000 | 0.000 |

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

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
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(U) Other Program Funding Summary Cost:

- Not Applicable.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | | | R-1 ITEM NOMENCLATURE Materials & Biological Technology PE 0602715E, R-1 # 18 | | | | |
| COST (In Millions) | FY 2004 | FY2005 | FY2006 | FY2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 0.000 | 256.480 | 294.188 | 299.844 | 304.784 | 315.107 | 316.107 | 323.107 |
| Materials Processing Technology MBT-01 | 0.000 | 166.330 | 177.790 | 172.617 | 175.750 | 184.772 | 185.772 | 192.772 |
| Biologically Based Materials and Devices MBT-02 | 0.000 | 90.150 | 116.398 | 127.227 | 129.034 | 130.335 | 130.335 | 130.335 |

(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. This program element was created in accordance with congressional intent in the FY 2005 DOD appropriations bill. Prior year funding was budgeted in PE 0602712E, Projects MPT-01 and MPT-09.

(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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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | R-1 ITEM NOMENCLATURE Materials & Biological Technology PE 0602715E, R-1 # 18 | |

| | | | | |
|------------|--|-----------------------|-----------------------|-----------------------|
| (U) | <u>Program Change Summary:</u> <i>(In Millions)</i> | <u>FY 2005</u> | <u>FY 2006</u> | <u>FY 2007</u> |
| | Previous President's Budget | 249.336 | 246.897 | 240.175 |
| | Current Budget | 256.480 | 294.188 | 299.844 |
| | Total Adjustments | 7.144 | 47.291 | 59.669 |

Please note that this program element has been newly created from several projects previously funded in PE 0602712E. The *Previous President's Budget* amount reflects projects MPT-01 and MPT-09 funded under that PE.

| | |
|----------------------------------|--------|
| Congressional program reductions | -7.856 |
| Congressional increases | 15.000 |
| Reprogrammings | 0.000 |
| SBIR/STTR transfer | 0.000 |

(U) **Change Summary Explanation:**

| | |
|----------------|---|
| FY 2005 | Increase reflects congressional adds for six materials programs offset by a congressional program reduction to Biofabrication and undistributed reductions. |
| FY 2006 - 2007 | Increase reflects additional efforts in the Materials for Logistics program and additional efforts in the area of prosthetic technology and increases in other biological programs. |

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | | | R-1 ITEM NOMENCLATURE Materials & Biological Technology PE 0602715E, Project MBT-01 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Materials Processing Technology MBT-01 | 0.000 | 166.330 | 177.790 | 172.617 | 175.750 | 184.772 | 185.772 | 192.772 |

(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 for improvements in logistics. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602712E, Project MPT-01 and is noted as a memo entry in the programs below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|----------------------------------|----------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Structural Materials and Devices | (33.790) | 42.271 | 49.000 | 48.617 |

(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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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602715E, Project MBT-01 | |

(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 portable, low-logistics protective system to protect troops against 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 fabrication (forming, joining, etc.) technologies that yield bulk amorphous metals suitable for Defense applications, especially those that require high fracture toughness, even at high strain rates, and quantify the impact of using bulk amorphous materials in construction of land vehicles and naval vessels.
- Demonstrate and validate solutions to 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.
- 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.
- Explore concepts and demonstrate materials technologies for large, ultra-lightweight and controllable space structures.
- Develop unique, three dimensional approaches for making and replicating materials and structures of interest to DoD.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602715E, Project MBT-01 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------|----------|---------|---------|---------|
| Smart Materials and Actuators | (30.000) | 36.059 | 40.000 | 40.000 |

(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.
- 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).
- Extend morphing concepts to expand military capabilities of air vehicles, transatmospheric vehicles and orbiting systems including lightweight, reconfigurable optics.
- Develop ultra-light high temperature capable materials systems for hypersonic vehicles using novel approaches to enable reduced thermal load, boundary layer control and virtual shape control.
- Develop materials, devices, and systems for urban conflict including approaches for moving in the third dimension, compact, expandable barriers, tamper resistant or tamper evident door and window coverings, and traction reducing agents for impeding foot and wheeled traffic.
- 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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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602715E, Project MBT-01 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|----------|---------|---------|---------|
| Functional Materials and Devices | (20.000) | 33.000 | 40.790 | 37.000 |

(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 smart, multifunctional fibers that may be woven into textiles to provide revolutionary capability for warfighter uniforms and equipment; for autonomous vehicles, and space structures.
- 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.
- Develop new functional material amenable to slowing, storing and manipulating light.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | | R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602715E, Project MBT-01 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Materials for Logistics (Air, Water, Power) | (28.852) | 40.000 | 48.000 | 47.000 |

(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. 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 portable power sources in the 20 Watt power range suitable for several mission scenarios including: 1) a 3 hour micro air vehicle reconnaissance mission; 2) a 3 day land warrior mission; and 3) a 10 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/cm²) 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.
- 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.

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- Demonstrate processes that can convert military waste to usable military logistic fuels.
- Design bioelectrocatalysts that are compatible to both the environment of the fuel cell, the electrolyte, and electron transport to the electrode.
- Develop sediment and water column fuel cell prototype systems; investigate systems concepts for hybrid powered surveillance platforms capable of maintaining a sustained presence, especially undersea or at high altitudes.
- Explore unconventional power sources that might yield new, efficient approaches to providing power to the battlefield.
- Establish the feasibility of using micro power sources for engineering and generating enzymatic and microbial catalysts for bio fuel cells (e.g., directed evolution).
- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------|---------|---------|---------|---------|
| Heat Actuated Coolers | (1.200) | 0.000 | 0.000 | 0.000 |

(U) Program Plans:

- Continued to develop compact, lightweight microtechnology-based cooling systems to take advantage of the availability of portable cooling in military and civilian applications where electric power is not available, but waste heat is plentiful.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------|---------|---------|---------|---------|
| Friction Stir Welding | (1.200) | 1.300 | 0.000 | 0.000 |

(U) Program Plans:

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

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------------|---------|---------|---------|---------|
| Advanced Materials Research Institute | (1.800) | 0.000 | 0.000 | 0.000 |

- (U) Program Plans:
- Developed nano devices fabricated by bottoms-up fabrication techniques to form the basis for novel sensors and have the potential for information storage.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------|---------|---------|---------|---------|
| Materials Science Technology | (0.750) | 0.000 | 0.000 | 0.000 |

- (U) Program Plans:
- Continued development of a training program for advanced composite materials by tailoring university and community college programs to industry needs.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------|---------|---------|---------|---------|
| Strategic Materials | (4.250) | 3.400 | 0.000 | 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Advanced Materials for Electromagnetic Devices | 0.000 | 2.000 | 0.000 | 0.000 |

- (U) Program Plans:
- Develop nanoscale mechanical spin switches using a unique nanofabrication capability.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Cryo-Power Electronics Development for the All-Electric Ship Program | 0.000 | 1.300 | 0.000 | 0.000 |

- (U) Program Plans:
- Develop cryogenic electronics for the all electric navy through the establishment of a Cryogenic Electronics Center at Albany.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|---------|---------|---------|---------|
| MMI/MBI Nanotechnology Solutions | 0.000 | 2.000 | 0.000 | 0.000 |

- (U) Program Plans:
- Investigate new approaches and accelerate the research of leading-edge nano-scale technologies for potential Defense applications.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------|---------|---------|---------|---------|
| Sematech | 0.000 | 5.000 | 0.000 | 0.000 |

- (U) Program Plans:
- Establish an advanced semiconductor prototyping capability for innovative micro-scale and nano-scale technologies.
 - Develop approaches for processing and integration of soft and hard materials based on a silicon-centric platform.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research | R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602715E, Project MBT-01 | |

(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 Materials & Biological Technology PE 0602715E, Project MBT-02 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Biologically Based Materials and Devices MBT-02 | 0.000 | 90.150 | 116.398 | 127.227 | 129.034 | 130.335 | 130.335 | 130.335 |

(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. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602712E, Project MPT-09 and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|--------------------------------------|----------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Bioinspired and Bioderived Materials | (35.296) | 40.000 | 40.000 | 44.000 |

(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:

- Explore soft materials (e.g., actuators, adhesives) in biological systems for potential Defense applications.
- Demonstrate bio-inspired materials that manipulate troop-based chemical and electromagnetic emissions to increase troop survivability.
- Demonstrate biomimetic sensory prototypes and materials that collect electromagnetic olfactory and visual inputs.
- Develop sensors, inspired by certain biological organisms' ability to transmit and sense electromagnetic energy, for use as navigational and target discrimination/identification aides in maritime environments.
- 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.
- 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 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.).
- 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.
- Adapt biologically inspired communication/sensing modalities to improve operations in extreme environments (jungle, urban).

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------|----------|---------|---------|---------|
| Biochemical Materials | (24.000) | 36.500 | 43.398 | 45.227 |

(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. This effort is supported by basic research on fundamental biological mechanisms in PE 0601101E, Project BLS-01.

(U) Program Plans:

- Demonstrate induced desiccation strategies for platelets and red blood cells that allow prolonged periods (> 24 months) of dry storage and recovery. Evaluate efficacy of the blood products in the battlefield environment.
- 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 for maintaining functional and physiokinetic endurance by nutritional and physical methods that are rapidly inducible, reversible and minimize the need for caloric intake while maintaining both strength and endurance.
- Develop methods for regulating core body temperature and hydration to maintain physical performance and endurance when training.
- Demonstrate the capability to transfer biochemical processes chemically or physically to cells, tissues, organs, systems, and organisms lacking robust survival mechanisms.
- Develop an understanding of effect of non-lethal physical forces on biological responses, including traumatic brain injury.

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- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------|---------|---------|---------|---------|
| Bio-Fabrication | (3.000) | 3.500 | 6.000 | 10.000 |

(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. A specific target for demonstration within this program is the development of 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.

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- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Bio-Magnetic Interfacing Concepts (BioMagnetICs) | (8.514) | 10.150 | 12.000 | 8.000 |

(U) The Bio-Magnetic Interfacing Concepts (BioMagnetICs) Materials program will develop and demonstrate novel capabilities for integrating nanomagnetism with biology and will demonstrate the advantages of magnetism 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 magnetism 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. This effort is supported by basic research on fundamental biological mechanisms funded in PE 0601101E, Project BLS-01.

(U) Program Plans:

- Develop and demonstrate a portable, magnetism-based DNA detection and readout capability for rapid determination of specific biological warfare agents.
- Develop and demonstrate a capability for non-invasive, non-destructive imaging of intracellular activity.
- Develop and demonstrate remotely addressable, magnetism-based biochemical sensors.
- Develop and demonstrate the capability to magnetically manipulate and actuate cellular functions such as apoptosis, reproduction, and gene expression.
- Develop and demonstrate the capability to use magnetism to rapidly filter biotoxins from humans.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|---------|---------|---------|---------|
| Revolutionizing Prosthetics | (0.000) | 0.000 | 15.000 | 20.000 |

(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 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 and actuators that are both biocompatible and emulate form and function of natural biological limbs.
- Develop and demonstrate distributed microprocessors and sensors with required bandwidth and sensitivity.
- 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/or discomfort wearing the prosthetic.
- Transition breakthrough technologies in control, healing, sensing, energetics, and design into prosthetic devices with performance approaching that of living limbs to the Veteran’s Administration and Walter Reed Medical Center.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| University of Florida Biosensor/Biomotive Nano Technology | (1.700) | 0.000 | 0.000 | 0.000 |

(U) Transitioned research into methodologies for designing, fabricating and demonstrating different kinds of novel bio-molecular assemblies that form transducing elements between chemical, electrical, optical and mechanical phenomena.

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

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY2005 | FY2006 | FY2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 0.000 | 261.406 | 241.736 | 249.453 | 250.501 | 250.425 | 250.425 | 250.425 |
| Electronics Technology ELT-01 | 0.000 | 261.406 | 241.736 | 249.453 | 250.501 | 250.425 | 250.425 | 250.425 |

(U) **Mission Description:**

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

(U) Advances in microelectronic device technologies, including digital, analog, photonic and microelectromechanical (MEMS) devices, continue to have significant impact in support of defense technologies for improved weapons effectiveness, improved intelligence capabilities and 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 program element was created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0602712E, Projects MPT-02 and MPT-08 and is noted as a memo entry in the programs below.

(U) **Program Accomplishments/Planned Programs:**

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------------|----------|---------|---------|---------|
| Adaptive Focal Plan Arrays (AFPA) | (10.175) | 7.503 | 5.274 | 3.039 |

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Vertically Interconnected Sensor Arrays (VISA) | (12.681) | 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 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 (PE0603739E).

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Terahertz Imaging Focal-Plane Technology (TIFT) | (7.542) | 9.625 | 10.000 | 10.000 |

(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

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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.

(U) Program Plans:

- Demonstrate revolutionary component and integration technologies necessary for the development of a diffraction-limited, video-rate THz (at least 0.557×10^{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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| 3-D Microelectromagnetic RF systems (3-D MERFS) | (4.130) | 4.924 | 4.736 | 1.970 |

(U) The 3-D Microelectromagnetic RF systems (3-D MERFS) program will develop complete millimeter wave active arrays on a single or a very small number of wafers. The program will exploit new technologies being developed commercially that allow GaAs active components to be placed on Si wafers, and advances in InP and SiGe 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, robotics and small remotely piloted vehicles. This program will build upon technology developed under the Vertically Interconnected Sensor Array program.

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- (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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Analog Optical Signal Processing (AOSP) | (12.538) | 8.500 | 0.000 | 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.

- (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.

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- Construct testbeds capable of fully characterizing the photonic -based RF signal processing components.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Advanced Precision Optical Oscillator (APROPOS) | (7.914) | 4.904 | 4.599 | 2.150 |

(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 insert in system testbeds.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Advanced Digital Receiver | (0.000) | 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).

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- (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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------|----------|---------|---------|---------|
| Chip Scale Atomic Clock | (17.957) | 12.840 | 7.828 | 5.500 |

(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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Technology Efficient, Agile Mixed Signal Microsystem (TEAM) | (15.137) | 16.332 | 12.570 | 7.000 |

(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.

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- (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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST) | (21.996) | 18.591 | 10.014 | 0.000 |

(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.

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- (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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------|---------|---------|---------|---------|
| Clockless Logic | (5.800) | 4.900 | 4.700 | 0.000 |

(U) The Clockless Logic program goal 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.

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- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Optoelectronics for Coherent Optical Transmission & Signal Processing | (0.000) | 0.000 | 5.604 | 7.500 |

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Design Tools for 3-Dimensional Electronic Circuit Integration | (10.921) | 11.843 | 10.649 | 11.272 |

(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 tools needed to fully exploit a true 3-D technology for producing high performance circuits. The deliverables from this program will have a

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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 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------------|---------|---------|---------|---------|
| Chip-to-Chip Optical Interconnects | (3.197) | 9.000 | 6.425 | 3.000 |

(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 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 than 10 GBps), low power (less than 50 mW) optical transmitter/receivers.
 - Integrate optical transmitters/receivers and optical data paths with electronic packaging and manufacturing approaches.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Multiple Optical Non-redundant Aperture Generalized Sensors (MONTAGE) | (0.000) | 5.454 | 4.766 | 2.172 |

(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.

(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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| High Frequency Wide Band Gap Semiconductor Electronics Technology | (24.778) | 12.000 | 20.000 | 20.000 |

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

(U) 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 SiC and wide band gap alternate substrates with less than 80 micropipe/cm² and resistivity 10⁶ ohms-cm.
- Demonstrate epitaxial processes that yield + 3 percent uniformity over 75 mm wide bandgap substrates.
- 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/cm² and resistivity 10⁷ 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/cm² and resistivity greater than 10⁷ 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/cm² power density in high power devices.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| High Power Wide Band Gap Semiconductor Electronics Technology | (11.241) | 13.877 | 10.000 | 15.000 |

(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 cm² 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 cm² consistent with 10 kV reverse blocking.
- Initiate work on Megawatt class SiC power device able to switch at more than 100 kHz.
- Initiate work on packaging of high power density, high temperature SiC power electronics.
- Demonstrate megawatt Class SiC power devices.
- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Robust Integrated Power Electronics (RIPE) | (6.660) | 3.000 | 5.286 | 8.310 |

(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

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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.

- (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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------|---------|---------|---------|---------|
| UltraBeam | (0.000) | 3.087 | 2.344 | 2.000 |

(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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Submillimeter Wave Imaging FPA Technology (SWIFT) | (0.000) | 4.100 | 8.000 | 13.000 |

(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. This program is utilizing technology developed in the Terahertz Technology Program funded in PE0601101E, Project ES-01.

(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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Direct Analog To Target ID - Non-Linear Math for Mixed Signal Microsystems | (0.000) | 3.254 | 3.270 | 3.286 |

(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.

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- Work with new classes of quantization devices based on novel “error correcting” representations of numbers, such as beta encoders, phase encoders, geometric invariants.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|---------|---------|---------|---------|
| Integrated Nano-Electronics | (0.000) | 0.000 | 4.000 | 8.000 |

(U) The Integrated Nano-Electronics Program will develop a technology for reliably integrating conventional integrated circuits with critical nano-scale devices, such as nanotubes, nanowires, and quantum effect structures. These types of nano-scale devices exhibit operational and physical behaviors based on the fundamental physics of the materials and configurations of the device. Nano-scale technologies can make highly functional devices, with low-loss interconnects and thermal mitigation, resulting in new classes of sensors. Based on their size and physical properties, nano-scale devices can have performance advantages in non-volatile memories, implementation of memory-intensive electronic functions such as image processing, as well as optical and millimeterwave RF sources through plasmon resonances. Also, nano-scale devices can make extremely sensitive physical sensors that can be coupled closely to low power sensor processors. In this program, critical nano-scale materials and process technologies will be developed that are compatible with semiconductor fabrication and can be inserted into a regular design flow. Individual or unstructured masses of nanotubes, nanowires, nanoparticles, and quantum structures are readily fabricated with leading-edge equipment and materials. This program will develop cost-effective technologies for producing bulk materials that are needed as process precursors and will develop the compatible fabrication and integration technologies necessary to create high performance integrated nano-electronic circuits for defense applications, based on exploiting inherent nano-scale device properties with conventional electronics.

(U) Program Plans:

- Develop physical fabrication techniques for nano-scale devices, focusing on establishing core unit processes compatible with an integrated flow.
- Develop efficient simulation techniques and boundary models for static and transient modeling of integrated nano-scale and micro-scale components.
- Demonstrate metrology for measuring critical parameters and functional state variables associated with nano-scale wires and devices.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Terascale Integration for Scalable Mixed Signal Microsystems | (0.000) | 5.000 | 6.000 | 10.000 |

(U) This program will develop semiconductor technologies that provide substantial increases in the integrated performance of entire suites of electronic components that are used for signal generation, detection, and processing, focusing on mixed signal electronics, such as analog/RF/digital chips. This program will result in increased functional densities for highly integrated circuits with low power dissipation, and will pursue innovative nano-scale silicon devices and circuits that will enable precision mixed signal circuits for DoD critical applications.

(U) Program Plans:

- Develop designs for fiber optic connectors that exploit highly integrated (millions of transistors) of nano-scale devices into mixed signal circuits to open up new approaches to creating precision mixed signal systems-on-chip for processing and generating high performance, tailored signals for DoD applications.
- Identify and exploit new device operational modes and chip microarchitectures to allow high performance, low power, and adaptable/reconfigurable circuits and creating an overall design environment that effectively maps complex system problems into efficient silicon IC solutions.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------|---------|---------|---------|---------|
| Radioisotope Micropower Sources | (0.000) | 8.392 | 11.137 | 13.014 |

(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.

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- (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 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------|---------|---------|---------|---------|
| 3-D Directed MicroAssembly | 0.000 | 0.000 | 2.000 | 4.000 |

(U) This research program will develop novel technologies for the rapid and automated directed assembly of large numbers ($> 10^6$) of prefabricated micron-scale parts into three dimensional meso-scale (millimeter to meter sized) multifunctional active structures and robotic systems. Using these technologies will allow fabrication of structures comprised of individual components with mechanical, sensory, and computational capabilities that perform complex functions (much as biologically produced structures do) of military interest.

- (U) Program Plans:
- Exploit innovative ideas in fluidic self-assembly and massively parallel microactuator systems.
 - Explore both industry and university work on precise “pick and place” operations on large numbers of components.
 - Demonstrate the capability to (1) select and position parts based upon their location in a 3-D structure, (2) bond/weld the parts into position, and (3) establish interconnects as required to provide for internal communication and power.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Universal Photonic Interface for High Dynamic Range Antenna (U-PHO) | (0.000) | 0.000 | 6.000 | 8.000 |

(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 EW antenna applications.

(U) Program Plans:

- Integrate to allow tunable frequency and impedance matching to arbitrary antenna structures, with adaptive pre-distortion, feedback and feed-forward linearization schemes to achieve >135 dB SFDR (1 Hz).
- Transition into airborne, space and maritime platforms where wideband communications, radar and EW apertures, with size, weight and power advantages are needed.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Polymorphous Computing Architecture (PCA) | (15.015) | 23.056 | 10.938 | 10.020 |

(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 process from years down to minutes. Current DoD embedded computing systems can be characterized as static in nature, relying on hardware-driven, heterogeneous point-solutions that represent static architectures and software optimizations. The program breaks the current development approach of hardware first and software last by moving beyond conventional silicon to flexible polymorphous computing systems. The key efforts of this revolutionary step forward in embedded computing systems are: 1) define critical reactive computing requirements and critical micro-architectural features; 2) explore, develop and prototype reactive polymorphous computing concepts; 3) explore, develop and prototype multi-dimensional verification and validation techniques for dynamic reactive missions; and 4) provide early experimental testbeds and prototype polymorphous computing systems; and 5) extend PCA to enable early commercial

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product development and transition to the DoD and intelligence communities. The result will be a new generation of on-board, embedded computing processing capability that will be mission and technology invariant 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 now be achieved over the life of a typical DoD embedded computing system. The program will also develop interactive, real-time terrain computation, visualization and manipulation to support Computer Generated Forces (CGFs), specifically the OneSAF (One Semi-Automated Forces). This effort will leverage commercial graphic processing units (GPU) and early PCA program streaming technology to provide key technology transitions.

(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.
- Develop and demonstrate line-of-sight and collision computations using GPU.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Antimonide Based Compound Semiconductors (ABCS) | (10.346) | 0.000 | 0.000 | 0.000 |

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

(U) Program Plans:

- Substrate Technology. Accelerated recent breakthroughs in lateral epitaxial overgrowth and thin film delaminating and rebonding to develop a source for ABCS substrates with essentially any desired thermal and/or electronic property.
- Electronics Integration. Raised levels through a series of demonstrations of analog, digital or mixed signal circuits with increasing device count which have beyond state-of-the-art performance in terms of frequency of operation and low power consumption.
- Demonstrated robust semi-insulating ABCS substrate material.
- IR sources. Exploited the unique bandgap engineering approaches available with the ABCS family of materials to increase the operation temperature above 230 degrees Kelvin and extend emission over the Long-Wave Infrared (LWIR) range.
- Achieved multi-watt output, array technology along with increases in efficiency for individual devices.
- Delivered first six multi-batch ABCS substrates.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD) | (10.336) | 0.000 | 0.000 | 0.000 |

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

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- (U) Program Plans:
- Developed Model Order Reduction methods (for analog and photonic devices) to enable the creation of behavioral models.
 - Developed and demonstrated top-down design capabilities for analog, mixed signal and mixed electronic/photonic systems that match the efficiency currently achieved with digital designs.
 - Developed fast solvers for analog and photonic devices; performed non-linear model order reduction, developed extraction tools, synthesized capabilities for mixed signal and mixed electronic/photonic circuits, and developed interfaces with existing digital tools to enable co-simulation.
 - Demonstrated the tools for designing and prototyping selected mixed electronic/photonic circuits and mixed signal systems (e.g., Analog-to-Digital Converters) for military applications.
 - Developed a design methodology for analog, mixed signal and mixed electronic/photonic systems utilizing:
 - Analog behavioral models in a digital design environment.
 - Extraction methodologies for analog and photonic devices.
 - Synthesis and layout rules for analog and photonic devices.
 - Hierarchical design libraries.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------|----------|---------|---------|---------|
| Moletronics | (13.330) | 0.000 | 0.000 | 0.000 |

(U) The molecular electronics (Moletronics) program pursued the concept that integration of multiple molecules, nanotubes, nano-wires, etc., into scalable, functional devices that are interconnected to the outside world would enable lower power operation, a wide range of operating temperatures and much greater device density. This research also demonstrated the scalability of molecular scale electronics to circuits containing 10^{11} elements and for densities equivalent to $10^{11}/\text{cm}^2$ and show that hierarchical self-assembly processes can be employed to build molecular circuits. The technologies explored in the Moletronics program formed the basis for the on-going Applications of Molecules Electronics program.

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(U) Program Plans:

- Characterized and optimized molecular-based devices such as switches, multi-state molecules and molecules exhibiting highly non-linear characteristics such as negative differential resistance.
- Demonstrated that nano-wires have conductivities near that of bulk metal or better.
- Quantified the defect-tolerance required for a molecular-based computer to still function.
- Developed hierarchically directed assembly processes to assemble molecular devices, wires and interconnects.
- Demonstrated efficient defect-search algorithms.
- Modeled the scalability of molecular circuit architectures to high counts and high device densities.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Applications of Molecular Electronics (MoleApps) | (11.120) | 4.608 | 10.020 | 10.110 |

(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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Quantum Information Science and Technology (QuIST) | (27.692) | 25.437 | 0.000 | 0.000 |

(U) The Quantum Information Science and Technology (QuIST) program will explore all facets of the research necessary to create a new technology based on quantum information science. Research in this area has the ultimate goal of demonstrating the potentially significant advantages of quantum mechanical effects in communication and computing. 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 scalability to large numbers of bits. Error correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Signal attenuation will be overcome by exploiting quantum repeaters. New algorithm techniques and complexity analysis will increase the selection of algorithms, as will a focus on signal processing. Scalable solid-state technologies will integrate thousands of qubits on a single device. Expected impacts include highly secure communications, algorithms for optimization in logistics and wargaming, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking. Additionally, QuIST will also pursue technologies to build and demonstrate a scalable quantum information processor that will address issues such as architecture and manufacturability. The computing technologies developed in QuIST are being continued and applied in the Focused Quantum Systems program. Additionally, quantum technologies for secure communications will be further developed in another program.

(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, computation, and memory; demonstrate high-rate (1 Gbit/sec) quantum-secure communication over a single link; transition quantum-secure communication to existing DoD mobile testbed.
- Employ scalable qubit architectures to demonstrate an application of interest to the DoD (e.g., quantum repeater, secure metropolitan-area network).

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------|---------|---------|---------|---------|
| Focused Quantum Systems (FoQuS) | (0.000) | 13.753 | 24.703 | 24.110 |

(U) The FoQuS program will develop a path toward an advanced quantum information processor drawing on the fundamental understanding and foundations developed under the QuIST program which is also funded in this project. Key elements for such a processor include architectural development, quantum memory, input/output (I/O) interfaces, state synthesizers, and nanofabrication of materials and devices. The specific goal of the program is to significantly accelerate the development of a quantum computer, with the aim of building a quantum information processor in a decade rather than a score of years, as projected by the current roadmap.

(U) Program Plans:

- Develop solid state and other potentially scalable technologies.
- Leverage substantial investment already made by semiconductor industry in materials infrastructure.
- Develop industry participation to provide the discipline necessary for ultimate manufacturability of a quantum processor.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| CAD-QT (Cognitively Augmented Design for Quantum Technolgy) | 0.000 | 0.000 | 2.320 | 0.000 |

(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.

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- (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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Solid State Imager/Extended Range Materials | (0.000) | 0.000 | 5.000 | 10.000 |

(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.

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

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Advanced Microsystems Technology Program | (0.000) | 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 SOI circuits to InP 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 Si CMOS for DoD applications.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------|---------|---------|---------|---------|
| HyperX | (0.000) | 0.000 | 3.500 | 10.000 |

(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 $\geq 500\text{MHz}$ and consume $\leq 250\text{milliwatts}$).
 - Develop Integrated Hardware/Software Design Environment Software.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|---------|---------|---------|---------|
| Energy Starved Electronics (ESE) | (0.000) | 0.000 | 3.495 | 10.000 |

(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 subthreshold (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.

(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.
- Develop and demonstrate fault-tolerant methodology for digital circuits to minimize effects of process variations and small signal margins.
- Explore architectures to minimize the power dissipation of circuits in sub-threshold operation while keeping performance constant.
- Establish fundamental limits of energy dissipation of digital circuits taking into account process variations and device impairments (e.g., leakage).
- Identify and enhance the process/device technology that provides highest performance, lowest leakage circuits for operation at < 300mV.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Optical Arbitrary Waveform Generation (AWG) | 0.000 | 0.000 | 6.000 | 10.000 |

(U) The ultimate vision for the Optical Arbitrary Waveform Generator (AWG) program is to demonstrate a compact, robust, practical, stable octave-spanning optical oscillator, and to demonstrate the ability to independently encode/decode (both via amplitude and phase modulation) all individual frequency components of such an octave-spanning oscillator with an update rate approaching 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 optical waveforms with fractional bandwidths approaching 10.
 - Demonstrate system applications of Optical AWGs that are of high military interest.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Fabrication of 3D Structures/Characterization, Reliability, & Application | (2.000) | 1.800 | 0.000 | 0.000 |

(U) The goal of the Fabrication of Three Dimensional Structures program is to investigate multi-chip module technology.

- (U) Program Plans:
- Continued 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Center for Optoelectronics and Optical Communications | (2.500) | 5.000 | 0.000 | 0.000 |

(U) The Center for Optoelectronics and Optical Communications program is investigating advances in optical communications.

- (U) Program Plans:
- Continued optoelectronic and optical communications development.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| NanoElectronics Defense and Security Initiative | (0.000) | 1.500 | 0.000 | 0.000 |

- (U) Program Plans:
- Develop cryo-electronic components for use in large military power systems. The initial focus is on Navy Ship Power Conversion.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------|---------|---------|---------|---------|
| Nanoscale Organic Spintronics | (0.000) | 1.400 | 0.000 | 0.000 |

- (U) Program Plans:
- Synthesize and characterize organic compounds for solid state devices using electronic spins and construct solid state devices from 2 and 3 qubit molecular systems.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------------|---------|---------|---------|---------|
| Nano Photonic Systems Fabrication | (1.000) | 0.000 | 0.000 | 0.000 |

(U) This program focused on the development of new materials for nano-optics.

(U) Program Plans:

- Prepared new materials for applications in lasers and nano-inspired optics.
- Enhanced nano-photonic systems fabrication capabilities for DoD by concentrating on unique technologies for photonic device fabrication, integration and packaging.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Integrated Nano and Micro-manufacturing | (1.000) | 0.000 | 0.000 | 0.000 |

(U) This program sought to develop new nano and micro-manufacturing technologies.

(U) Program Plans:

- Initiated development of advanced nano and micro-manufacturing technologies.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Testing & Evaluation of Advanced Composites | 0.000 | 1.400 | 0.000 | 0.000 |

(U) This program will initiate development of testing and evaluation processes for advanced composite materials.

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|---|-----------------------|-----------------------|-----------------------|
| (U) <u>Program Change Summary:</u> (In Millions) | <u>FY 2005</u> | <u>FY 2006</u> | <u>FY 2007</u> |
| Previous President's Budget | 252.708 | 239.588 | 254.860 |
| Current Budget | 261.406 | 241.736 | 249.453 |
| Total Adjustments | 8.698 | 2.148 | -5.407 |

Please note that this program element was established in accordance with congressional intent in FY 2005. FY 2004 and prior was funded under PE 0602712E. The Previous President's Budget amounts reflect projects MPT-02 and MPT-08.

| | |
|----------------------------------|--------|
| Congressional program reductions | -2.402 |
| Congressional increases | 11.100 |
| Reprogrammings | 0.000 |
| SBIR/STTR transfer | 0.000 |

(U) Change Summary Explanation:

FY 2005 Increase reflects congressional adds for five electronics programs offset by congressional undistributed reductions.
 FY 2006 - 2007 Changes reflect minor repricing.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Advanced Aerospace Systems PE 0603286E, R-1 # 32 | | | | |
| COST (In Millions) | FY 2004 | FY2005 | FY2006 | FY2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 0.000 | 71.420 | 75.866 | 111.029 | 120.377 | 115.923 | 90.923 | 80.923 |
| Advanced Aerospace Systems AIR-01 | 0.000 | 71.420 | 75.866 | 111.029 | 120.377 | 115.923 | 90.923 | 80.923 |

(U) Mission Description:

(U) The Advanced Aerospace Systems program element is budgeted in the Advanced Technology 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. This program element was created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0603285E, Project ASP-01 and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------|----------------|----------------|----------------|----------------|
| A160 | (9.000) | 9.000 | 7.000 | 5.000 |

(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 (more than 2,000 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, lethal and non-lethal weapons delivery, assured 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

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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 compatibility. DARPA established an MOA with the Army for this program in April 2003. The A160 program will transition to the Army in the summer of FY 2006.

(U) Program Plans:

- Fabricate and test low vibration rotor modifications.
- 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.
- Flight test low vibration four-blade rotor modifications.
- Conduct tests of advanced engines and coordinate with development of high-efficiency heavy fuel engine technologies.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Joint Unmanned Combat Air System (J-UCAS) | (41.385) | 0.000 | 0.000 | 0.000 |

(U) The Joint Unmanned Combat Air System (J-UCAS) program is a joint effort to develop and demonstrate unmanned combat capabilities for high-threat Suppression of Enemy Air Defense (SEAD); Information Operations/Intelligence, Electronic Attack (EA), Persistent Surveillance/Reconnaissance, and related strike missions within the emerging global command and control architecture for the warfighting community.

(U) The J-UCAS program combines and expands the efforts that were previously conducted under the DARPA/Air Force Unmanned Combat Air Vehicle (UCAV) program and the DARPA/Navy Naval UCAV (UCAV-N) program. Although these efforts were targeted towards Service-specific needs, the Department recognized the potential for significant synergy by combining the programs. The accomplishments and ongoing efforts of the X-45A technology demonstrator, as well as the development of the X-47A demonstrator, are reducing the risk of the “operationalized” demonstration system being developed for a joint operational assessment (OA) planned for the FY07-10 timeframe. The J-UCAS concept incorporates the next generation family of air vehicles, together with common subsystems (e.g. sensors, payloads, communications), and a Common Operating System to achieve the system’s diverse mission functionality. These common system elements will

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maximize mission flexibility and operational versatility, while reducing overall costs and maintaining schedule toward a joint operational assessment.

(U) In 2003, the Department established a joint service J-UCAS Office that includes DARPA, Air Force, and Navy personnel, operating in close coordination with Service users and other components. Service and DARPA funding for the J-UCAS in FY 2005 has been consolidated in two new program elements (PE 0603400D8Z and PE 0604400D8Z). In FY 2005, OSD directed that the program be transitioned to the Air force beginning in FY 2006.

(U) Program Plans:

- Continued development of J-UCAS systems, specifically the Boeing and Northrop Grumman demonstrator programs as well as the common operating system and sensors.
- Prepared for joint operational assessment (OA).

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Unmanned Combat Armed Rotorcraft (UCAR) | (35.432) | 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 complete at the end of Phase II.

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- (U) Program Plans:
- Completed system trades, effectiveness, and affordability analyses through modeling and simulation.
 - Develop sufficient system concept fidelity to validate program goals and objectives.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Quiet Supersonic Platform | (3.370) | 0.000 | 0.000 | 0.000 |

(U) The Quiet Supersonic Platform (QSP) program was directed towards development and validation of critical technology for long-range advanced supersonic aircraft with substantially reduced sonic boom, and increased efficiency relative to current-technology supersonic aircraft. Improved capabilities include supersonic flight over land without adverse sonic boom consequences with boom overpressure rise less than 0.3 pounds per square foot, increased unrefueled range approaching 6,000 nmi, gross take-off weight approaching 100,000 pounds, increased area coverage and lower overall operational cost. Highly integrated vehicle concepts were explored to simultaneously meet the cruise range and noise level goals. Advanced airframe technologies including optimized configuration shaping and laminar flow control were explored and shown to be viable to minimizing sonic boom and vehicle drag. Accomplishments include subscale model wind tunnel testing of low drag technology in a simulated flight environment and computational fluid dynamics calculations. In an effort to demonstrate configuration-shaping technology, plans were completed for a modified F-5 using a wing glove design. Once the flight test vehicle design was deemed suitable, parts fabrication and installation were completed. Flight tests successfully validated that optimized vehicle configurations produce shaped sonic boom signatures through the atmosphere to the ground. These flight tests demonstrated a low noise signature for supersonic aircraft. Advances in sonic boom reduction have transitioned to industry.

- (U) Program Plans:
- Conducted high fidelity wind tunnel test of large-scale semi span wing design to simulate actual supersonic flight conditions.
 - Initiated preliminary design of laminar flow control technology integrated into flight test vehicle.
 - Performed computational fluid dynamics calculations and conducted low and high speed wind tunnel tests of flight test vehicle to assess safety of flight.
 - Conducted flight-testing to validate low drag technology in real flight environment.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------------|---------|---------|---------|---------|
| Advanced Aeronautics Demonstration | (7.523) | 14.519 | 20.000 | 25.000 |

(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 three projects, the Canard Rotor/Wing (CRW), Heliplane, and Oblique Wing concepts.

(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. Completion of current flight testing will determine whether a follow-on program is warranted.

(U) The Heliplane, an alternative VTOL concept, is an air vehicle which offers a factor of two improvement in speed and range over conventional helicopters. Such improvements support a diverse mission set including Search and Rescue (SAR), fleet logistical supply, ship to shore sea basing, and future force requirements for tactical maneuver. Fabrication and flight testing of scaled vehicle demonstrators will validate the aerodynamic performance and stability and control system required for VTOL operation and efficient high speed cruise.

(U) The Oblique Wing aircraft is a flying wing which flies “end-on” to improve high speed characteristics. Building from the oblique wing and formation flying concepts, the program will integrate additional technologies, such as laminar flow and articulated propulsion to develop and fly two 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.

- (U) Program Plans:
- Upgrade second CRW air vehicle and complete demonstrator flight tests.
 - Continue design studies of follow-on CRW manned and unmanned vehicles.

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- Conduct risk-reduction ground tests on key heliplane system components.
- Complete detailed design of heliplane vehicle demonstrator.
- Fabricate heliplane demonstrator aircraft.
- Conduct flight tests to validate heliplane performance.
- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------------|---------|---------|---------|---------|
| Cormorant Unmanned Air Vehicle (UAV) | (2.149) | 6.984 | 9.600 | 5.100 |

(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 dynamics at the air/sea interface, engine technology to survive periodic immersion in salt water, and development of advanced composite materials 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 risk reduction experiments for materials and subsystems.
 - Prepare preliminary design and conduct preliminary design review.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------|---------|---------|---------|---------|
| Heavy Fuel Engine for A160 | (4.426) | 6.687 | 6.612 | 2.729 |

(U) The Heavy Fuel Engine for 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 concepts will be developed to achieve both efficiency and a significant reduction in weight. The engine to be developed will enable the A160 to achieve maximum range and endurance while operating on diesel fuel. The A160 Engine Development technology is planned for transition to the Army at the conclusion of Phase III, which is anticipated to be completed by FY 2007.

- (U) Program Plans:
- Detail design of the engine.
 - Demonstrate performance goals of a prototype engine at 33% efficiency and a power to weight ratio of 0.83 hp/lb.
 - Demonstrate performance and reliability of optimized engines at 39% efficiency and a power to weight ratio of 1.0 hp/lb.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------|---------|---------|---------|---------|
| Walrus | (0.000) | 0.000 | 0.000 | 20.000 |

(U) This work focuses on system application of technologies and concepts being developed and reported under PE 0602702E, Tactical Technology Project TT-07, Aeronautics Technology. The Walrus program will develop and evaluate a very large airlift vehicle concept that is designed to control 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 will generate lift through a combination of aerodynamics, thrust vectoring and gas buoyancy generation and management and for much of the time, it will fly heavier than air. The program will develop an operational vehicle concept and will conduct risk reduction demonstrations notably including a Walrus Advanced Technology Demonstration (ATD) air vehicle. The ATD vehicle will demonstrate scalable aircraft technology, is anticipated to achieve comparable C-130 airlift capability, and will explore, develop, and demonstrate the system concepts of operation. The Walrus objective vehicle will have a primary mission to deploy composite loads of personnel and equipment (for

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example, the components of a Unit of Action) ready to fight as they disembark from the aircraft within 6 hours after landing. Walrus will operate without significant infrastructure and from unimproved landing sites, ostensibly flat but over rough ground to tolerate 5 foot high obstacles. It will carry a useful payload >500 tons over global distances (12,000nm in less than 7 days) at a competitive cost. Additionally, Walrus will be capable of performing theater lift, support of Sea Basing and persistence missions to meet a range of multi-agency needs. Advanced breakthrough technologies will be investigated in the first phase to support the development of lift and buoyancy concepts. The program's first phase will include system studies and development of a notional concept of the objective vehicle. Based on these studies and concept viability, the competitive second phase will lead to the development of an objective air vehicle design, fabrication and initial flight test of the ATD risk reduction vehicle. The Walrus technology is being coordinated with the Army, Navy, and Air Force for possible transition. Transition to selected organization(s) is planned to occur after FY 2008.

(U) Program Plans:

- Development of the objective air vehicle design, operating missions and CONOPs.
- Competitive development of potential objective vehicle system concepts and preliminary ATD vehicle design based on selected concept options.
- Selection of the preferred objective air vehicle system design concept and development to preliminary design level review.
- Risk reduction demonstrations in support of the objective vehicle including the key ATD vehicles.
- Complete detailed design of the ATD air vehicle leading to a critical design review.
- Manufacture and fabricate ATD air vehicle.
- Flight test and release to Services for evaluation testing of military utility.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------|---------|---------|---------|---------|
| Critical Munition Capability | (2.500) | 6.500 | 9.000 | 9.000 |

(U) The Critical Munition Capability program consists of three efforts: HyperJAM (Hypersonic Joint Attack Munition), MAULLM (Multi-target Autonomous Loitering Littoral Munition), and BEDLAM (Battlefield Electronically Disruptive Loitering Attack Missile). 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

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forces. The MAULLM and BEDLAM programs build upon developments from the NetFires program previously funded from PE 0603764E, Land Warfare Technology, Project LNW-03.

(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 and test 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. MAULLM builds on and extends many of the concepts developed in NetFires, will be air deployable in C-130 (and smaller) aircraft, and will enhance the situation awareness and survivability of the Navy and Marines by providing standoff target acquisition and extended-range, non-line-of-sight engagements. The program will develop and demonstrate a highly flexible, modular, multimission loitering missile that can be remotely commanded and can send target detection and battle damage information back to the controller.

(U) BEDLAM will develop critical components and 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. The program will develop or enhance a number of key components: extremely sensitive transceivers capable of detection of extremely low-level electronic signals; signal processing algorithms to separate signals of interest from other electronic clutter; direction finding and mapping techniques to track multiple emitters; and antenna arrays suitable for wide-frequency operation; and will integrate these elements into a mission module suitable for small loitering missiles or UAVs. If successful, this will provide improved capabilities in several areas: a single missile can detect and engage air defense assets even after they cease transmissions or begin to move; low-level emissions from cell phones and computer networks can be detected and relayed or targeted; and target-specific emissions detected by other systems (such as Wolfpack) can be acquired and correlated with other co-located emissions even while moving to establish patterns or meetings with other emitters to aid in intelligence and targeting. This program will leverage both the DARPA NetFires and Wolfpack programs.

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- (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.
 - Conduct technology risk reduction effort of solid fuel ramjet or rocket engine development/integration.
 - Conduct technology risk reduction effort on adaptive inlet concepts.
 - Evaluate preliminary designs and downselect for development of HyperJam prototype.
 - Conduct ground experiments to evaluate engine performance on munition in unguided flight tests.
 - Conduct flight demo experiments in simulated military mission.

 - MAULLM
 - Develop and demonstrate critical technologies including next-generation Automatic / Assisted Target Recognition and novel low-cost reduced-signature airframe concepts.
 - Evaluate communication and command and control technologies and select best option(s).
 - Evaluate preliminary designs and downselect to best design(s).
 - Develop brassboard seekers and submunitions and perform flight tests against a variety of targets.
 - Downselect or modify design based on flight test data and develop form factored MAULLM prototype.
 - Perform flight tests with loitering missile in simulated military mission.

 - BEDLAM
 - Initiate competitive contracts for system preliminary design.
 - Obtain and present data from representative emitters to determine performance boundaries.
 - Evaluate emerging antenna concepts and select best option(s).
 - Evaluate preliminary designs and downselect to best design(s).
 - Develop brassboard module and perform flight tests against a variety of emitters.
 - Downselect or modify designs based on flight test data and develop form factored module for loitering missile.

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-- Perform flight tests with loitering missile in simulated military mission.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Modular Blended Wing Body Multi-Role Aircraft (MBWB MRA) | (0.000) | 6.420 | 0.000 | 0.000 |

(U) The goal of the MBWB MRA program is to develop and demonstrate a system that can efficiently and affordably meet the Joint Service needs for a bomber, tanker, and transport. The inherently high lift-to-drag ratio and payload fraction of the MBWB MRA will enable weapons, fuel, materiel, and personnel to be transported 25-50 % more efficiently than is possible with current aircraft. The MBWB MRA will be reconfigurable on the flight line to a bomber, tanker, or transport in less than 24 hours. Commercial derivatives of the MBWB MRA will carry freight at a cost per air ton mile that is 20-40 % below that of existing aircraft.

(U) This program will develop and demonstrate technology to enable large scale composite manufacturing, advanced flight controls, modular payloads, and separation of stores. Structural characteristics will be validated through destructive testing of panels. Aerodynamic control, store separation, and aerodynamic performance will be demonstrated through wind tunnel models. A 40-50 % scale aircraft will be designed, fabricated, and demonstrated.

(U) Program Plans:

- Perform system trades and develop conceptual designs.
- Develop large scale composite manufacturing technology.
- Develop modular mission modules.
- Develop aerodynamic control technologies.
- Develop store separation technology.
- Fabricate a 40-50 % scale model of a MBWB MRA.
- Demonstrate capability to reconfigure as a bomber, tanker, and transport.
- Demonstrate efficiency and affordability.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------------|---------|---------|---------|---------|
| Advanced Aerospace System Concepts | (3.281) | 3.310 | 3.254 | 2.200 |

(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 war fighter 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------|---------|---------|---------|---------|
| Reusable Space Plane | (0.000) | 0.000 | 0.000 | 25.000 |

(U) The Reusable Space Plane 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, this program will further mature, integrate and flight-demonstrate propulsion technologies developed by the 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

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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.

- (U) Program Plans:
- Mature scramjet flow path.
 - Integrate turbine and scramjet engines.
 - Conduct ground testing of combined cycle engine.
 - Conduct flight-test demonstration.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| High Angle Ballistic Instrumented Test (HABIT) | (0.000) | 0.000 | 14.000 | 17.000 |

(U) Information on the performance of ballistic materials is required in conditions that cannot be created in ground test facilities. A very high velocity, very high angle flight test of an inert test article is required to create these unique conditions. The test article will be instrumented to act as a “flying laboratory” to collect this information, which is needed for a variety of future hypersonics programs. The high angle ballistic instrumented test (HABIT) program will conduct analysis, design, and fabrication of the low-cost flight test article, and will culminate in a test flight.

- (U) Program Plans:
- Evaluate candidate technologies and instrumentation approaches for design and development of the test article.
 - Perform modeling and simulation of anticipated flight and instrumentation performance and fabricate test article.
 - Conduct flight test, data collection and analysis.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------|---------|---------|---------|---------|
| Long Gun | (3.850) | 8.000 | 6.400 | 0.000 |

(U) The Affordable Weapon System (AWS) Long Gun program was previously funded under PE 0603764E, Project LNW-03. The Long Gun program will evaluate and develop a re-useable, long endurance, low cost, joint, unmanned/armed missile system combined with a tri-mode long wave infrared/near infrared/visible (LWIR/NIR/VIS) sensor with laser spot targeting. Ducted fan propulsion will provide efficient thrust for long endurance. The missile will be launched from a canister carried on a sea or ground vehicle, will fly to a specified target area, and use a tri-mode sensor operating at visible, long, and near-infrared wavelengths to search for targets. If a qualified target is found, the missile will attack the target with a self-contained munition. If no targets are found, the missile could be commanded to return to base. The missile will include a data link back to a human controller/operator to confirm target characteristics, approve engagement, and perform battle damage assessment.

(U) Program Plans:

- Modify existing AWS airframe as basis for missile design.
- Replace engine with ducted fan with rotary engine operated with heavy fuel.
- Develop and integrate tri-mode sensor/seeker with laser spot recognition for targeting.
- Develop avionics package to support long-endurance flight.
- Conduct inert flight tests and demonstrate long endurance operation.
- Demonstrate weapons dispense along rail to simulate weapon release.
- Demonstrate multiple air vehicles controlled by a single operator.
- Integrate sensor fused weapons into payload bay.
- Conduct flight tests and live simulation weapon dispensing demonstration.

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|---|-----------------------|-----------------------|-----------------------|
| (U) <u>Program Change Summary:</u> (In Millions) | <u>FY 2005</u> | <u>FY 2006</u> | <u>FY 2007</u> |
| Previous President's Budget | 111.847 | 147.573 | 161.512 |
| Current Budget | 71.420 | 75.866 | 111.029 |
| Total Adjustments | -40.427 | -71.707 | -50.483 |

Please note that this program element was established in accordance with congressional intent in FY 2005. FY 2004 and prior was funded under PE 0603285E. The Previous President's Budget amount reflects project ASP-01.

| | |
|----------------------------------|---------|
| Congressional program reductions | -40.427 |
| Congressional increases | 0.000 |
| Reprogrammings | 0.000 |
| SBIR/STTR transfer | 0.000 |

(U) Change Summary Explanation:

FY 2005 Decrease reflects congressional undistributed reductions and a \$10 million program reduction for Walrus.
 FY 2006 - 2007 Decrease reflects reduced funding for the Unmanned Combat Armed Rotorcraft and Walrus programs.

(U) Other Program Funding Summary Cost:

| | | | | |
|---|---------|---------|---------|---------|
| Joint Unmanned Combat Air System (J-UCAS) | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| PE 0604731F, Air Force | 160.551 | 0.000 | 0.000 | 0.000 |
| PE 0207256F, Air Force | 2.300 | 0.000 | 0.000 | 0.000 |

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|---|---------|---------|---------|---------|
| PE 0603400F, Air Force | 0.000 | 0.000 | 77.800 | 0.000 |
| PE 0604400F, Air Force | 0.000 | 0.000 | 272.300 | 400.100 |
| PE 0603114N, Navy | 102.865 | 0.000 | 0.000 | 0.000 |
| PE 0603400D8Z, OSD | 0.000 | 354.794 | 0.000 | 0.000 |
| PE 0604400D8Z, OSD | 0.000 | 217.401 | 0.000 | 0.000 |
| Unmanned Combat Armed Rotorcraft (UCAR) | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| PE 0602211, Project 47A, Army | 0.000 | 0.000 | 0.000 | 0.000 |
| PE 0603003, Project 313, Army | 4.200 | 0.000 | 0.000 | 0.000 |
| A160 | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Army S&T, Phase I | 10.000 | 15.000 | 10.000 | 15.000 |
| Army S&T, Phase II | 0.000 | 0.000 | 9.190 | 18.740 |

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| COST (In Millions) | FY 2004 | FY2005 | FY2006 | FY2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 0.000 | 222.880 | 223.811 | 264.291 | 309.256 | 327.428 | 348.678 | 350.678 |
| Space Programs and Technology SPC-01 | 0.000 | 222.880 | 223.811 | 264.291 | 309.256 | 327.428 | 348.678 | 350.678 |

(U) Mission Description:

(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. This program element was created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0603285E, Project ASP-02 and is noted as a memo entry within each program.

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(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Orbital Express Space Operations Architecture | (44.418) | 46.599 | 38.750 | 15.550 |

(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. In addition, a servicing satellite can support deployment and operations of micro-satellites for missions such as space asset protection and sparse aperture formation flying, or deploy nano-satellites for inspection to provide data to support satellite repair. 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 on the Hubble Space Telescope robotic servicing mission and to enable 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.
- Develop conceptual designs for nano-satellite servicing assistants.
- Perform utility assessments of on-orbit servicing in conjunction with operational customers and plan for technology transition.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------|----------|---------|---------|---------|
| Space Surveillance Telescope | (10.621) | 18.673 | 18.592 | 12.842 |

(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 and novel optics design to build a telescope with a large aperture that provides detection sensitivity with a low-aberration wide field-of-view to provide rapid wide-area search coverage. 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 contributing sensor to the Air Force Space Surveillance Network. An MOA is being established with Air Force Space Command for transition the conclusion of Phase II, that is anticipated to be completed by FY 2009.

- (U) Program Plans:
- Begin optics fabrication.
 - Complete full mosaic tile fabrication.
 - Begin wide-field camera integration.
 - Begin processing and control software development.
 - Begin telescope integration.
 - Begin site preparation.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Innovative Space-Based Radar Antenna Technology (ISAT) | (41.208) | 46.000 | 45.000 | 43.000 |

(U) The Innovative Space-Based Radar Antenna Technology (ISAT) effort will develop radically new enabling technologies and design methods for extremely large space-based RF antenna technologies necessary for tactical-grade ground moving target indicator (GMTI) radar. Up to 300m 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. An antenna of this size

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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). ISAT technology also enables the detecting and tracking of all airborne targets using a constellation of 12 to 14 satellites in a high LEO orbit. The ISAT program will retire the risk associated with two major technical obstacles: 1) the reliable and controllable deployment of a ~300m long 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------|---------|---------|---------|---------|
| Novel Satellite Communications | (0.000) | 4.900 | 8.500 | 16.000 |

(U) The aim of the Novel Satellite Communications (NSC) program (formally known as Microsatellite Tactical Communications Network (MTCN)) is the development of an advanced, affordable, multi-user satellite communications (SATCOM) system using a medium earth orbit

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(MEO) constellation that allows ground-based users with the Joint Tactical Radio System (JTRS) 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 novel spacecraft design, advanced low-weight, highly compactable antennas, and novel signal processing and coding techniques.

- (U) Program plans:
- Develop novel NSC system and spacecraft designs.
 - Determine feasibility of novel signal processing concepts to enable robust communications.
 - Carry out proof-of-concept demonstrations.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------|---------|---------|---------|---------|
| Deep View | (9.520) | 14.250 | 10.250 | 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.

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- Integrate into a low-power configuration in FY 2007, providing LEO-only capability.
- Demonstrate LEO-GEO imaging capability using a full set of gyro-twistrons.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Responsive Access, Small Cargo, Affordable Launch (RASCAL) | (31.802) | 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 (MIPCC) 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 MPV and ERV development portions of the program will not continue into Phase III. MIPCC testing and experiments will be conducted to demonstrate the utility of the propulsion augmentation technology.

(U) Program Plans:

- Developed Contractor Life Cycle Cost Model (CLCC).
- Selected preferred system concept(s).
- 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.
- Continue prototype Mass Injection Pre-Compressor Cooling (MIPCC) manifold – engine testing.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Tactically Responsive Satellites (TRS) | (5.016) | 3.800 | 0.000 | 0.000 |

(U) The TRS program will develop 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 may play a role in under 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 will be transitioned to the newly formed Air Force Tactical Satellite (TACSAT) program at the end of FY 2005.

- (U) Program Plans:
- Evaluate the feasibility of candidate TRS missions.
 - Develop candidate designs for tactically responsive warfighter payloads.
 - Develop and mature key enabling technologies.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------|----------|---------|---------|---------|
| Falcon | (17.500) | 12.500 | 25.000 | 50.000 |

(U) The Falcon (formerly HyperSoar) program objectives are to develop and demonstrate hypersonic technologies that will enable the capability to execute 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 an 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

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implement this flight test program in an affordable manner, 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 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 NASA for this program 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:

- Preliminary design for HTV-1 technology flight demonstration vehicle completed.
- Complete SLV preliminary designs.
- Conduct early launch demonstrating responsive operations.
- Perform technology validation simulation and ground tests for hypersonic flight.
- Conduct SLV full scale motor 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Rapid On-Orbit Anomaly Surveillance and Tracking (ROAST) | (5.000) | 7.000 | 2.000 | 2.000 |

(U) The Rapid On-Orbit Anomaly Surveillance and Tracking (ROAST) program will develop technologies to enable low-cost, responsive spacecraft and capabilities, such as space situational awareness and blue force tracking. Key payload technologies will include light-weight optics,

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adaptive focal plane array sensors, and efficient space-qualified receivers and processors. The system will feature space-craft 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:
- Demonstrate light-weight, large area optics fabrication capability.
 - Complete telescope design.
 - Develop focal plane array, read out electronics, data processing hardware and algorithms.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| High Frequency Active Auroral Research Project (HAARP) | (15.944) | 15.006 | 0.000 | 0.000 |

(U) The High Frequency Active Auroral Research Project (HAARP) will develop new experimental research capabilities and will conduct 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 is 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 are: (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) 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 indicate that 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 recent study completed by an Air Force/Navy Panel also points to additional high-value functions that can potentially be accomplished with the a 3.6 MW

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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 for this program in August 2002. The HAARP technology is planned for transition to the Air Force and Navy in FY 2006.

- (U) Program Plans:
- Complete the HAARP high frequency transmitting array at the HAARP Research Station, Gakona, AK.
 - Prepare the existing HAARP facility in preparation for ionospheric testing.
 - Conduct advanced ionosphere and radio science research and analysis of applications including space-based asset protection and phenomena related to its implementation.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------|---------|---------|---------|---------|
| Sleight of HAND (SOH) | 0.000 | 5.810 | 10.482 | 15.450 |

(U) This program is an outgrowth of and 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 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 operational 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.

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- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Suborbital Space Launch Operations / Improving Suborbital Operations | (1.500) | 4.800 | 0.000 | 0.000 |

(U) The goal of the Suborbital Space Launch Operations/Improving Suborbital Operations program is to develop and demonstrate a piloted, reusable suborbital launch vehicle initially to perform short duration testing of space flight hardware, and ultimately to provide a platform for tactical battlefield surveillance.

- (U) Program Plans:
- Design and test a restartable propulsion system for ascent and descent.
 - Develop payload concepts for battlefield surveillance and sensor insertion.
 - Develop a preliminary system design for the launch vehicle.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------|---------|---------|---------|---------|
| Space Assembly and Manufacture | (4.200) | 6.792 | 10.000 | 15.000 |

(U) The goal of the Space Assembly and Manufacture program is 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 will enable novel structures that could not survive the loads experienced during terrestrial launch. Extremely large structures enable resolution and accuracy from optical and radar systems that are not otherwise conceivable. Such structures are important to antennas, optics, solar collectors and other technologies to address both national security and energy issues. The Space Assembly and Manufacture program will comprise resource utilization, robotic processing, enabling structures, micro-satellite sensors, propellants and power generation. Manufacturing processes, such as vacuum deposition, extrusion,

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nanotube fabrication, etc., that can take advantage of the space environment will be included. Mass and complexity minimization of key components will drive the design of the system.

(U) The DARPA Space Robotics program will develop technologies for, and demonstrate the utility of, multi-jointed electromechanical arms for a variety of space servicing tasks. Traditional approaches to space vehicle servicing and docking require custom fittings and docking aids. One focus of the Space Robotics program will be to demonstrate an automated approach to proximity operations and grapple that do not require modifications to the spacecraft design. The program will first demonstrate the ability to locate, grapple, and assist a spacecraft in a ground based demonstration. Missions for a robotic space tug include repositioning, retirement maneuvers, and rescue of stranded spacecraft. Ultimately, this versatile technology will also be useful for repair of spacecraft anomalies, and for robotic assembly of large space structures and complex space systems that are launched into orbit in separate small modules that must then be assembled on orbit. The technology will also be useful for civil and commercial spacecraft operations.

(U) Program Plans:

- Identify key technical challenges and define a demonstration mission to resolve critical issues for space manufacture.
- Develop microsatellite and other sensor platforms that can determine chemical composition and location of resources on non-terrestrial objects.
- Design, fabricate and test miniaturized robotics capable of remotely processing materials and building rudimentary structures.
- Perform utility assessments of space manufacture in conjunction with operational customers and plan for technology transition.
- Create realistic docking models and solar lighting conditions in a proximity operations simulation facility.
- Conduct demonstration in proximity operations simulation facility of dockings with a variety of realistic spacecraft geometries, lighting conditions, and relative motion.
- Develop a preliminary design of the demonstration space vehicle.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------|---------|---------|---------|---------|
| Electro-Dynamic Tethers | (0.000) | 2.800 | 0.000 | 0.000 |

(U) The Electro-Dynamic (ED) Tethers program will demonstrate novel military space applications of tether-like structures. These include high-voltage electro-static designs that rapidly remediate high energy radiation particles produced by a High Altitude Nuclear Detonation (HAND). ED tethers also provide novel propulsion and power generation by alternating the direction of the electric current flow along its length in the presence of the magnetic field and plasmasphere. This will enable the potential for a transformational military space propulsion and energy source—without the use of consumables—when an ED tether is attached to a satellite. Although the concept of an ED tether is feasible, several technology advances are required to make it practical. In particular, extremely long ED tethers are required (~10 km) to provide sufficient Lorentz force for orbital boost and/or inclination change, impulsive energy generation due to a drop in altitude, as well as timely HAND remediation. Other issues to be addressed include: multi-kilometer structure dynamic stability and control during deployment, retraction and operation; electro-dynamic coupling efficiency to the plasmasphere without the use of consumables; and electrostatic influence on highly energetic, manmade charged radiation particles.

(U) Program Plans:

- Completed analytical analysis for tether HAND remediation, propulsion and power generation performance expectation.
- Develop candidate ES tether system design.
- Ground test key high-voltage electro-dynamic tether components.
- Flight qualify tether space flight experiments payload for placement on a small, high-powered satellite bus.
- Space demo to facilitate transition as part of the Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP).

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------|---------|---------|---------|---------|
| Micro Electric Space Propulsion | (0.000) | 3.800 | 2.762 | 0.659 |

(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 sec. to 10,000 sec. 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 s and 7000 s 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.
- Initiate propellant selection and optimization.
- Demonstrate thruster / propellant material compatibility.
- Demonstrate thruster operation.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------|---------|---------|---------|---------|
| RAD Hard by Design | (8.946) | 10.250 | 4.500 | 0.000 |

(U) This program, formerly titled Radiation Resistant Mixed Signal Electronics, will develop, characterize, and demonstrate the mixed-signal Rad by Design solution with assured access to commercial foundry for low volume applications. This program will develop and demonstrate

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microelectronic design technologies to enable fabrication of radiation hardened electronic components through 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 niche military market. 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP) | (0.000) | 6.600 | 7.000 | 11.000 |

(U) The Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP) program, expanding on a thrust area initiated under the Space Assembly and Manufacture and RAD Hard by Design programs, also budgeted under this project, will develop the advanced technologies, capabilities and space environment characterization required to demonstrate a suite of advanced lightweight microsatellite technologies integrated into high performance microsattelites across the continuum from low earth orbit (LEO) to deep space (Super geosynchronous 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

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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 microsattellites/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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------|---------|---------|---------|---------|
| Space Awareness (SPAWN) | (0.000) | 0.000 | 14.000 | 24.000 |

(U) The goal of the Space Awareness (SPAWN) program is to provide near field space situational awareness (SSA) around U.S. satellites and offboard satellite anomaly resolution. Assuring the ability to operate in space is essential for the conduct of U.S. military operations and assured operations cannot be guaranteed without situational awareness. An offboard capability to diagnose satellite anomalies will reduce the time required to restore satellites to fully mission capable status. The SPAWN program will determine the capabilities needed for performing near-field SSA and satellite anomaly resolution, develop new technologies or modify existing systems to provide situational awareness and anomaly detection, and create an architecture that parses these capabilities between new and existing systems. SPAWN will leverage lightweight, space-qualified telescope technology developed under the ROAST program, and provide risk reduction for future Air Force systems.

(U) Program Plans:

- Design and develop architecture and CONOPS for SSA and offboard anomaly resolution.
- Develop conceptual designs for SPAWN systems and modifications, identify enabling technologies, and parameterize capabilities.

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- Develop, design, and fabricate, and test prototype technologies and techniques.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------|---------|---------|---------|---------|
| System F6 | (0.000) | 0.000 | 9.135 | 17.000 |

(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, in unison, 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, and 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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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Space Programs and Technology PE 0603287E, R-1 # 33 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Spacecraft for the Unmanned Modification of Orbits (SUMO) | (0.000) | 0.000 | 12.640 | 22.340 |

(U) The goal of the Spacecraft for the Universal Modification of Orbits (SUMO) program, an expansion of the robotics work initiated under the Space Assembly and Manufacture program, also budgeted under this project, is to design, develop and demonstrate 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. SUMO will enable continued safe operations, and service life extension to these spacecraft. SUMO combines detailed stereo photogrammetric imaging with robotic multi degree of freedom manipulators to autonomously grapple space objects without custom interfaces. SUMO 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 SUMO program include: development and demonstration of an autonomous rendezvous and grapple front end system; an effective, low total ownership cost design for the SUMO system; and specific mission capabilities for low earth orbit (LEO) and geo-synchronous orbit (GEO).

- (U) Program Plans:
- Design fabrication and ground testing of the sensing and robotic payload using non-flight hardware.
 - Complete risk reduction lab demonstration.
 - Develop control algorithms for autonomous grapple and contingency operations.
 - Fabrication and procurement of flight hardware for integration and testing.
 - Robotic payload ground test.
 - Payload integration.
 - Test control schemes in “virtual space” environment.
 - Hardware-in-the-loop testing in proximity operations test facility.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| X-ray Navigation and Autonomous Position Verification (XNAV) | (0.000) | 2.300 | 5.200 | 9.200 |

(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. The XNAV ATD 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 gimbale 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.
- Space qualify payload.
- Conduct flight demonstration.
- Evaluate navigation performance.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | R-1 ITEM NOMENCLATURE Space Programs and Technology PE 0603287E, R-1 # 33 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------|---------|---------|---------|---------|
| Joint NASA/DoD Development | 0.000 | 8.500 | 0.000 | 0.000 |

(U) The Joint NASA/DoD Development program will coordinate related technology efforts between NASA and DARPA to ensure that both organizations derive 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 will build on insights gained in the design and development of Orbital Express to begin the design of robust in-space servicing elements and investigate optimum CONOPS for mixed robotic and crewed operations.

- (U) Program Plans:
- Design fuel transfer system for bi-propellant cryogenic fuel transfer system.
 - Develop CONOPS for manned- robotics collaboration in-space.
 - Design a robust proximity operations sensor suite based.

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| | | | | |
|------------|--|-----------------------|----------------------|----------------------|
| (U) | <u>Program Change Summary:</u> <i>(In Millions)</i> | <u>FY 2005</u> | <u>FY2006</u> | <u>FY2007</u> |
| | Previous President's Budget | 249.220 | 233.606 | 261.769 |
| | Current Budget | 222.880 | 223.811 | 264.291 |
| | Total Adjustments | -26.340 | -9.795 | 2.522 |

Please note that this program element was established in accordance with congressional intent in FY 2005. FY 2004 and prior was funded under PE 0603285E. The *Previous President's Budget* amounts reflect project ASP-02.

| | |
|---------------------------------|---------|
| Congressional program reduction | -39.640 |
| Congressional increases | 13.300 |
| Reprogrammings | 0.000 |
| SBIR/STTR transfer | 0.000 |

(U) **Change Summary Explanation:**

| | |
|---------|---|
| FY 2005 | Decrease reflects congressional reductions to Orbital Express, Rascal, CAV, and undistributed reduction offset by congressional adds for Improving Sub-Orbital operations and Joint NASA/DoD Development. |
| FY 2006 | Decrease reflects project rephrasing following discontinuation of the current RASCAL program. |
| FY 2007 | Increase reflects minor project repricing. |

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

| | | | | |
|---|---------|---------|---------|---------|
| Orbital Express Space Operations Architecture | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| NASA | 4.000 | 0.000 | 0.000 | 0.000 |

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | | |
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|--|---------|---------|---------|---------|
| High Frequency Active Auroral Research Project (HAARP) | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| PE 0601153N, Navy | 15.000 | 16.000 | 0.000 | 0.000 |
| PE 0602601F, Air Force | 10.000 | 10.000 | 10.000 | 0.000 |
| Falcon | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| PE 0604855, Air Force SPC | 22.344 | 30.362 | 23.354 | 16.000 |
| PE 0604856, Air Force SPC | 12.220 | 16.610 | 23.000 | 26.500 |
| NASA | 8.000 | 2.000 | 0.000 | 0.000 |

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
|---|---------|---------|---------|---|---------|---------|-----------------------|---------|
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, R-1 # 43 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 185.917 | 222.777 | 214.378 | 239.813 | 236.675 | 229.165 | 210.351 | 204.351 |
| Electronic Module Technology MT-04 | 18.682 | 15.408 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Centers of Excellence MT-07 | 4.700 | 5.000 | 4.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Advanced Lithography MT-10 | 31.701 | 28.370 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| MEMS and Integrated Micro-systems Technology MT-12 | 24.831 | 45.190 | 53.790 | 61.524 | 41.892 | 31.262 | 13.262 | 7.262 |
| Mixed Technology Integration MT-15 | 106.003 | 128.809 | 156.588 | 178.289 | 194.783 | 197.903 | 197.089 | 197.089 |

(U) Mission Description:

(U) The Advanced Electronics Technology program element is budgeted in the Advanced Technology Development Budget Activity because it seeks to design and demonstrate state-of-the-art manufacturing and process technologies for the production of various electronics and microelectronic devices, sensor systems, actuators and gear drives that have military applications and potential commercial utility. Introduction of 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 is a broad initiative to decrease the cost and increase the performance of weapon systems through the insertion of electronic modules. Electronic module technology addresses the design and fabrication of various types of digital, analog and mixed signal modules consisting of electronic, electro-optical and micro-mechanical components. Included in this project are the Semiconductor Ultraviolet Optical Sources (SUVOS), the Photonic Analog/Digital A/D Conversion, and the Chemical Engineering in Microsystems (CHEM) initiatives.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, R-1 # 43 | |

(U) Advanced Lithography technology has enabled the dramatic growth of integrated circuit capability. Advances have led to improvements in electronic and computing systems performance in terms of speed, power, weight and reliability. Further improvements require microcircuits with smaller features to meet the operational speed, power, weight and volume constraints.

(U) The Microelectromechanical Systems (MEMS) and Integrated Microsystems Technology project is a broad and cross-disciplinary initiative to develop an enabling technology that merges computation 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) | <u>Program Change Summary:</u> <i>(In Millions)</i> | <u>FY 2004</u> | <u>FY 2005</u> | <u>FY2006</u> | <u>FY2007</u> |
| | Previous President's Budget | 186.748 | 218.151 | 205.378 | 234.063 |
| | Current Budget | 185.917 | 222.777 | 214.378 | 239.813 |
| | Total Adjustments | -0.831 | 4.626 | 9.000 | 5.750 |

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| | | |
|----------------------------------|--------|--------|
| Congressional program reductions | 0.000 | -2.074 |
| Congressional increases | 0.000 | 9.700 |
| Reprogrammings | 0.000 | -3.000 |
| SBIR/STTR transfer | -0.831 | 0.000 |

(U) Change Summary Explanation:

| | |
|----------------|--|
| FY 2004 | Decrease reflects SBIR/STTR transfer. |
| FY 2005 | Increase reflects congressional adds for Embedded Intelligence, 3-D Imaging, Electro-Optic Imaging, Advanced Lithography and Mil-Tech Extension offset by congressional undistributed reductions and a \$3 million reprogramming to OSD for the Trusted Foundry. |
| FY 2006 - 2007 | Increase reflects project expansion of MT-15 for photonic fabric, resonant nanosensors and other mixed technology programs and additional funds for the Center of Excellence at Marshall University. |

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-04 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Electronic Module Technology MT-04 | 18.682 | 15.408 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

(U) Mission Description:

(U) The Electronic Module Technology Project is a broad initiative to substantially decrease the cost and increase the performance of weapon systems through the timely insertion of state-of-the-art electronic modules. Electronic module technology addresses the design and fabrication of various types of digital, analog and mixed signal modules consisting of electronic, electro-optical and micro-mechanical components. It includes traditional approaches such as printed circuit boards, and emerging technologies such as high density multichip modules. The project has three major objectives: (1) shorten the overall design, manufacture, test and insertion cycle for advanced electronic subsystems; (2) advance the state-of-the-art in electronic interconnection and physical packaging technology to allow circuits to operate close to their intrinsic maximum speed with less overhead in terms of volume, weight and cost; and (3) provide a robust manufacturing infrastructure for electronic modules.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|---|---------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Semiconductor Ultraviolet Optical Sources (SUVOS) | 16.832 | 10.408 | 0.000 | 0.000 |

(U) The Semiconductor Ultraviolet Optical Sources (SUVOS) program will develop photonic wide band gap materials for optical emission in the ultraviolet for bio sensing, and covert communications applications. This program will develop high conductivity *p*-type (positive charge carrier) material and highly efficient active region material suitable for ultraviolet emission, and exploit these results to enable the development of heterojunction bipolar transistors (HBT). The program will demonstrate short-wavelength semiconductor ultraviolet optical sources operating at wavelengths as short as 280 nm. Compared to conventional technologies, this program will achieve: 50x reduction of power requirements, 100x reduction of size and weight. This program will enable microsystems for biological agent detection, and covert non-line-of-sight (NLOS) tactical communications. The SUVOS technology is planned for transition to the Defense Threat Reduction Agency (DTRA) at the conclusion of Phase II, which is anticipated to be completed by the conclusion of FY 2005.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-04 | |

(U) Program Plans:

- Demonstrate *p*-type (positive charge carrier) doping in high aluminum concentration nitride materials at concentrations sufficient for minority carrier injection devices.
- Demonstrate minority carrier devices (e.g. light emitting diodes (LED), laser diodes, heterojunction bipolar transistors).
- Develop and demonstrate 340 nm laser diodes and LEDs.
- Develop and demonstrate < 280 nm laser diodes and LEDs.
- Demonstrate prototype microsystems based on SUVOS devices.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Chemical Engineering in Microsystems (CHEMS) | 1.850 | 5.000 | 0.000 | 0.000 |

(U) The CHEMS program will develop and demonstrate hardware and process control strategies for implementing practical and specific manipulation of the dynamics of matter at the molecular and atomic scale, ultimately leading to breakthrough capabilities in biochemical sensing and in high-value material synthesis and processing. The key technical capability developed in this program will be mechanisms for real-time control of ultrafast laser pulses for use as agile sensors, actuators, chaperones, and reagents for control of material system processes at the nanoscale. Technology developed in this program will transition through two small businesses that are developing robust commercialized pulse shaper modules for applications in chemical synthesis and analysis. Discussions are underway with representatives at Army Edgewood Chemical Biological Command and members of the Joint Services Metrology Group about potential applications of the technology in chemical sensing.

(U) Program Plans:

- Develop controlled adaptive laser pulses signature suitable for Mass Spectroscopic and Raman Spectroscopic read-out.
- Demonstrate adaptive laser pulse use in detection of low vapor pressure stimulant in gas phase and soil at a concentration 10 times lower than currently feasible.
- Demonstrate adaptive control of laser excited signature to enhance detection in the presence of interferents including diesel vapor, jet fuel, and aqueous film forming foam, pesticides and burning oil.
- Demonstrate excitation of molecules with shaped tailored light pulse at a distance of 100 meters for feasibility of retroemission of excited molecules for stand off detection.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-04 | |

- Demonstrate optical fractionation protocols for removing micrometer-scale impurities from biological samples of DoD interest, and for separation of bacteria (*B. subtilis*) from viruses as a step towards developing a new class of ultra-compact cytometers, potentially ideal for field-based analysis.
- Demonstrate optical high throughput sorting of condensed DNA by size, using commercially available DNA samples as models for developing the necessary protocols. This project will provide a proving ground for a new breakthrough approach to single-step multi-stage fractionation.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-07 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Centers of Excellence MT-07 | 4.700 | 5.000 | 4.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

(U) Mission Description:

(U) This project provides funding for the Robert C. Byrd Institute for Advanced Flexible Manufacturing at Marshall University. The Byrd Institute provides both a teaching 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) Program Accomplishments/Planned Programs:

| | | | | |
|---------------------------------|---------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Advanced Flexible Manufacturing | 3.950 | 4.000 | 4.000 | 0.000 |

(U) Program Plan:

- Continue the assessment of the Institute for Advanced Flexible Manufacturing's performance and transition from DoD to state/private support.

| | | | | |
|--|---------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Defense Techlink Rural Technology Transfer Project | 0.750 | 1.000 | 0.000 | 0.000 |

(U) Program Plan:

- Provide funding for the Defense Techlink Rural Technology Transfer Project.

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

- Not Applicable.

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|---|---------|---------|---------|--|---------|---------|-----------------------|---------|
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-10 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Advanced Lithography MT-10 | 31.701 | 28.370 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

(U) Mission Description:

(U) Microelectronics is a key to improved weapon system performance. Lithography technology has enabled the dramatic growth in microelectronics capability over the past three decades. The improved capabilities in semiconductor technology have contributed to significant system gains in speed, reliability, cost, power consumption and weight. Advanced microelectronics technology has been essential for computing and signal processing in virtually all military systems including command, control, communications and intelligence; electronic warfare; and beam forming for radar and sonar. Further improvements in areas such as target recognition, autonomous guided missiles and digital battlefield applications require microcircuits with smaller features to meet the operational speed, power, weight and volume constraints of these systems. Current microelectronics fabrication utilizes feature sizes of 0.13 microns. The Advanced Lithography program has emphasized longer-term research with expected high payoff in the fabrication of semiconductor devices with 0.05 micron or less feature sizes. These efforts will develop technology for sub 0.05 micron features.

(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------|---------|---------|---------|---------|
| Advanced Lithography | 22.101 | 24.520 | 0.000 | 0.000 |

(U) The goal of the Advanced Lithography program is to reduce technical barriers to the development of advanced lithographic technologies for the fabrication of a broad range of microelectronic devices and structures. Innovative research in pattern generation and transfer, imaging materials, new process and metrology will provide alternatives beyond current evolutionary trends. Maskless approaches will address the low volume needs of military systems. The program will investigate technologies for the creation of highly complex patterns at sub 0.05 μm resolution over field areas in excess of 1000 mm^2 . Applications with larger geometries will be explored for innovative devices and structures beyond microelectronics, including photonics and bio-arrays. These accomplishments will allow industry to fabricate prototype tools and new high-performance devices for use in advance military systems and commercial markets.

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(U) The Advanced Lithography program will also explore developments of key tool components, materials, and processing to accelerate the availability of emerging lithography technologies at 50nm and below. Efforts will include maskless approaches, imprint technologies, and innovative projection technologies. Developments in support technologies, common to several of the above, will include mask technology, resists, and metrology. The lithography program developments feature innovative designs and architectures, and new materials and processing beyond the evolutionary trends in the industry. The Advanced Lithography program is anticipated to transition via the semiconductor tool industry to integrated circuit manufacturers to meet state-of-the-art, cutting-edge semiconductor device technologies demanded by all Services.

- (U) Program Plans:
- Demonstrate key components of maskless wafer writer.
 - Demonstrate proof of concept tool for multibeam maskless lithography.
 - Deliver commercial imprint lithography tool with overlay of 50nm.
 - Demonstrate prototype tool for fabrication of devices with 50nm features.
 - Demonstrate key components for maskwriter for sub 0.05 micron features.
 - Demonstrate Extreme Ultra-Violet (EUV) source of 35 watts.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Laser Plasma X-Ray Source | 3.400 | 0.000 | 0.000 | 0.000 |

- (U) Program Plans:
- Continued development of laser plasma x-ray source technology.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------------|---------|---------|---------|---------|
| Advanced Lithography Demonstration | 3.400 | 3.850 | 0.000 | 0.000 |

- (U) Program Plans:
- Continued development of point source lithography.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-10 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Advanced Lithography X-Ray Thin Film Development | 2.800 | 0.000 | 0.000 | 0.000 |

- (U) Program Plans:
 – Continued development of x-ray mask lithography thin film.

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

- Not Applicable.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-12 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| MEMS and Integrated Micro-systems Technology MT-12 | 24.831 | 45.190 | 53.790 | 61.524 | 41.892 | 31.262 | 13.262 | 7.262 |

(U) Mission Description:

(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) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------|---------|---------|---------|---------|
| Micro Power Generation | 6.163 | 6.558 | 4.064 | 3.334 |

(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:

- Demonstrate capabilities in fuel processing, energy conversion to electricity, and thermal and exhaust management.
- Demonstrate 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Harsh Environment Robust Micromechanical Technology (HERMIT) | 8.002 | 12.657 | 10.042 | 10.190 |

(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 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------|---------|---------|---------|---------|
| Chip-Scale Gas Analyzers | 6.695 | 13.633 | 14.823 | 16.000 |

(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.
- 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).

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- Implement fully functional, MEMS-enabled gas separation analyzers with power consumptions small enough for autonomous, remote operation and with control electronics integrated directly.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------|---------|---------|---------|---------|
| MEMS Exchange | 3.971 | 4.114 | 3.067 | 1.385 |

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Chip-Scale Atomic Sensors | 0.000 | 0.000 | 7.000 | 12.000 |

(U) 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-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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------------|---------|---------|---------|---------|
| Low Power Micro Cryogenic Coolers | 0.000 | 8.228 | 14.794 | 18.615 |

(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

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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.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Mixed Technology Integration MT-15 | 106.003 | 128.809 | 156.588 | 178.289 | 194.783 | 197.903 | 197.089 | 197.089 |

(U) Mission Description:

(U) The goal of the Mixed-Technology Integration project is to leverage advanced microelectronics manufacturing infrastructure and DARPA component technologies developed in other projects to produce mixed-technology microsystems. These ‘wristwatch size’, low-cost, lightweight and low power microsystems will improve the battlefield awareness and security of the warfighter and the operational performance of military platforms. At the present time, systems are fabricated by assembling a number of mixed-technology components: Microelectromechanical Systems (MEMS), microphotonics, microfluidics and millimeterwave/microwave. Each technology usually requires a different level of integration occupies a separate silicon chip and requires off-chip wiring, fastening and packaging to form a module. The chip assembly and packaging processes produce a high cost, high power, large volume and lower performance system. This program is focused on the monolithic integration of mixed technologies to form batch-fabricated, mixed technology microsystems ‘on-a-single-chip’ or an integrated and interconnected ‘stack-of-chips’.

(U) The field of microelectronics incorporates micrometer/nanometer scale integration and is the most highly integrated, low-cost and high-impact technology to date. Microelectronics technology has produced the microcomputer-chip that enabled or supported the revolutions in computers, networking and communication. This program extends the microelectronics paradigm to include the integration of heterogeneous or mixed technologies. This new paradigm will create a new class of ‘matchbook-size’, highly integrated device and microsystem architectures. Examples of component-microsystems include low-power, small-volume, lightweight, microsensors, microrobots and microcommunication systems that will improve and expand the performance of the warfighter, military platforms, munitions and UAVs.

(U) The program includes the integration of mixed materials on generic substrates including glass, polymers and silicon. The program is design and process intensive, using ‘standard’ processes and developing new semiconductor-like processes and technologies that support the integration of mixed-technologies at the micrometer/nanometer scale. The program includes the development of micrometer/nanometer scale isolation, contacts, interconnects and ‘multiple-chip-scale’ packaging for electronic, mechanical, fluidic, photonic and rf/mmwave/microwave technologies. For example, a mixed-technology microsystem using integrated microfluidics, MEMS, microphotonics, microelectronics and microwave components could provide a highly integrated, portable analytical instrument to monitor the battlefield environment, the physical condition of a warfighter, the identity of warfighters (friend or foe) or the combat readiness of equipment. The ability to integrate mixed

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technologies onto a single substrate will drive down the size, weight, volume and cost of weapon systems while increasing their performance and reliability.

(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| RF Lightwave Integrated Circuits (RFLICS) | 3.195 | 0.000 | 0.000 | 0.000 |

(U) The Radio Frequency (RF) Lightwave Integrated Circuits (RFLICS) program demonstrated enhanced performance capabilities of RF systems enabled by integration of lightwave and RF technologies to route, control, and process analog RF signals in the 0.5 – 50 GHz range. The RFLICS program is transitioning to Army, Navy, and Air Force RF Photonics R&D efforts for further development and maturation in early FY 2005.

(U) Program Plans:

- Studied fundamental limits to RF communications links and perform system study.
- Defined critical technical challenges to increasing link margin by improving component linearity.
- Established program metrics for optimum RF link demonstration.
- Initiated component development and heterogeneous integration demonstrations.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Nano Mechanical Array Signal Processor (NMAASP) | 14.364 | 2.500 | 0.000 | 0.000 |

(U) The Nano Mechanical Array Signal Processors (NMAASP) will create arrays of precision; nano mechanical structures for radio frequency signal processing that will greatly reduce the size and power consumption of various communication systems. Technologies developed under the

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NMASP program will be transitioning through industry and are of interest to Army programs in low power radios and tactical communications, Air Force programs in wide band receivers, and Navy programs in precision frequency references.

(U) Program Plans:

- Demonstrate fabrication techniques to control surface morphology, geometry, and material properties at the sub-micron scale.
- Demonstrate temperature stability and electrical tenability of individual nano resonators suitable for UHF communication.
- Initiate development of nano mechanical array signal processors that will enable ultra miniaturized (wristwatch or hearing aid in size) and ultra low power UHF communicators/GPS receivers.
- Demonstrate several alternatives to achieve uniform arrays of up to 1024 nano resonators with geometrical control and material uniformity at $\pm 20\%$, and to $\pm 1\%$ with trimming and tuning.
- Demonstrate interconnection and isolation (multiplexed, serial, or random access) of individual resonators.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Digital Control of Analog Circuits RF Front Ends | 16.732 | 13.255 | 11.742 | 0.000 |

(U) Digital Control of Analog Circuits will demonstrate analog/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-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.
- Develop techniques and algorithms to monitor active device status.

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- 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 10⁵ 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 10⁵ 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Chip Scale Wavelength Division Multiplexing (CS-WDM) | 18.763 | 10.900 | 0.000 | 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.
- Plan construction of WDM components.
- Design, fabricate and test novel WDM components using the new materials and processing technology.

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- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Optical Code Division Multiple Access (CDMA) | 8.127 | 9.756 | 7.550 | 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 10 simultaneous users at 10 Gb/s 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Adaptive Photonic Phased Locked Elements (APPLE) (formerly titled Optical PAPA) | 0.000 | 5.875 | 10.000 | 15.000 |

(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.

- (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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Data in Optical Domain Network (DoD-Network) | 10.235 | 10.600 | 8.200 | 8.100 |

(U) This program was formerly named Intelligent Optical Networks. 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. This 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.

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- (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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Large Area Distributed Microelectronics | 5.500 | 6.400 | 6.100 | 6.000 |

(U) The Large Area Distributed Microelectronics 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. The Large Area Distributed Microelectronics program will be transferred to the Army's Flexible Display Center at the conclusion of Phase 3 in FY 2008. Commercialization will occur via the flexible electronics industry.

- (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.

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- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Microantenna Array Technology & Applications (MIATA) | 8.000 | 9.000 | 9.064 | 3.494 |

(U) This program was formerly named Submillimeter Wave Imaging Technology. The goal of this 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 Microantenna Array Technology and Applications 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------|---------|---------|---------|---------|
| Ultra Wide Band Technology | 8.837 | 14.660 | 17.939 | 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.

(U) The Ultra Wide Band Array Antenna program is developing novel electronic array antenna and beamforming technology. The program goal is 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. Each of the components is a significant advance in microwave technology. There are a variety of potential applications and the UWBA architecture will enable unprecedented sensitivity and coverage.

(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
 - Initiate critical component feasibility demonstration – radiating element, optical beamformer.
 - Extend initial designs to support 100: 1 instantaneous bandwidth.
 - Validate performance by simulation, begin component fab.
 - Complete component fabrication, verify component performance, and demonstrate beamformer approach.
 - Complete prototype integration and test - prove multi-octave, multi-beam performance.

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- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Flexible Nanocomposite Organic Photovoltaic Cells | 8.000 | 6.620 | 6.020 | 4.850 |

(U) The goal of the Flexible Nanocomposite Organic Photovoltaic (PV) Cells is 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 planned for transition to the United States Special Operations Command, Directorate of Advanced Technology (SOAL-T) at the conclusion of Phase IV in FY 2008. Commercial manufacturing is also anticipated which will improve the cost and availability of this technology for Service users.

- (U) Program Plans:
- Deliver 2 cm² PV cell with increased efficiency from < 3% to 20%.
 - Use plastic or fabric substrates in transparent electrode and heterojunction stability.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Laser-Photoacoustic Spectroscopy (L-PAS) | 0.000 | 7.516 | 6.674 | 6.284 |

(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.
- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Room Temperature - Mid-Wave Infrared with Integral Signal Processing | 0.000 | 0.000 | 8.953 | 15.000 |

(U) This program will develop new concepts in mid-wave detection to remove limitations, and lead the way to room temperature mid-wave imagers for use in multiple applications. In addition, new architectures for parallel signal processing at the detector can be applied to mid-wave focal plane arrays, integrating a three-dimensional architecture with the high speed image processing required for threat detection and missile warning. The integration of new concepts in mid-wave detector technology and parallel processing on the focal plane will provide a multi-band, mid-wave sensor module at less than one fourth the power consumption and size of current mid-wave imagers, expanding applications and establishing a new approach to high speed imaging.

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- (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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| MEMS Electronic & Photonic Integrated Circuits in Silicon | 0.000 | 7.000 | 10.000 | 15.000 |

(U) This program (formerly titled Silicon RFICS with MEMS) 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.

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- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Liquid Electronics Advanced Power Source (LEAPS) | 0.000 | 5.000 | 9.000 | 14.575 |

(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.

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Visible/Short Wave IR - Photon Counting | 0.000 | 0.000 | 6.000 | 15.000 |

(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

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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.
- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Electronic & Photonic Integrated Circuits on Silicon (EPIC) | 0.000 | 12.777 | 12.836 | 14.230 |

(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.

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- (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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Space, Time Adaptive Processing (STAP) BOY | 0.000 | 2.100 | 4.240 | 4.240 |

(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 an 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) a data adaptive algorithm: rank revealing QR, suitable for adaptive weight computations in STAP and 2) 3-D tomographic reconstruction processing for aperture synthesis.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------------|---------|---------|---------|---------|
| Combat Optical Fiber Technologies | 0.000 | 0.000 | 6.000 | 10.000 |

(U) The goal of this program is to demonstrate “wearable” photonic fabrics that can be optically manipulated so as to demonstrate multifunctional capabilities such as Identification-Friend-or-Foe (IFF), acoustic sensing and chemical sensing. Optical fibers with built in photonic crystals in a cylindrical symmetry structure will be developed. By either optically or electrically injecting carriers into the photonic crystals, a modulation of optical properties of the fiber occurs. This modulation can then be used for IFF, or sensing. The major impact will be in wearable material that can partially cover the soldier’s body, thus enabling either passive or active IFF, as well as sensors.

- (U) Program Plans:
- Develop optical fibers with built in photonics crystals.
 - Modulate optical properties of fibers.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Vertically Integrated Sensor Arrays (VISA) Applications | 0.000 | 0.000 | 6.270 | 15.000 |

(U) Prior year funding for the VISA program was budgeted in PE0602712E; Project MPT-02 and 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 (six to eight) 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.

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- (U) Program Plans:
- Develop low mass structures and high-Q resonators.
 - Develop nanoparticle mass-load tags for enhanced sensitivity.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------|---------|---------|---------|---------|
| Networked Microsystems | 0.000 | 0.000 | 10.000 | 16.000 |

(U) The purpose of the Networked Microsystems program is to develop an infrastructure that interacts with their environments. This will take advantage of networks of robustly-connected, heterogeneous sensor systems that exhibit great promise for protecting our forces from asymmetric threats. This program will investigate how networks of micro-sensors can be organized in intelligent ways so that sensor performance and hardware complexity at the device and circuit can be exploited.

- (U) Program Plans:
- Develop mathematical modeling and analysis of biological system dynamics.
 - Control adaptive, robust and scalable systems and develop control theory for Networked Microsystems.
 - Generate revolutionary approaches for deploying strategic and tactical groups of unmanned ground, air and sea vehicles.
 - Provide new capabilities in information dominance, decision-making, navigation and control, autonomous systems, dominant maneuvering, air traffic control, and embedded networks of sensors and actuators.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Novel Crystal Components for Imaging and Communications | 2.125 | 1.000 | 0.000 | 0.000 |

- (U) The goal of this program is to develop novel imaging technologies utilizing infrared (IR) and crystal growth approaches.
- (U) Program Plans:
- Continue the development of novel crystal components.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------------|---------|---------|---------|---------|
| 3-D Imaging Technology Development | 2.125 | 1.000 | 0.000 | 0.000 |

- (U) The 3-Dimensional Imaging Technology Development effort aims at developing 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:
- Demonstrate range imaging at the eye-safe wavelength of 1.54 micrometers with a minimum array size of 64 x 64.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Embedded Intelligent Migrating Symbolic Constructs | 0.000 | 2.850 | 0.000 | 0.000 |

(U) Develop technologies for embedded intelligent microsystems.

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

- Not Applicable.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Command, Control and Communications Systems PE 0603760E, R-1 # 46 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 189.062 | 219.765 | 216.408 | 220.918 | 257.552 | 267.296 | 256.872 | 257.884 |
| Command & Control Information Systems CCC-01 | 24.737 | 54.629 | 56.422 | 59.610 | 70.030 | 70.400 | 70.900 | 70.900 |
| Information Integration Systems CCC-02 | 114.453 | 99.146 | 108.384 | 110.907 | 124.295 | 128.795 | 127.985 | 127.985 |
| Classified CCC-CLS | 49.872 | 65.990 | 51.602 | 50.401 | 63.227 | 68.101 | 57.987 | 58.999 |

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)

| | <u>FY 2004</u> | <u>FY 2005</u> | <u>FY2006</u> | <u>FY2007</u> |
|----------------------------------|----------------|----------------|---------------|---------------|
| Previous President's Budget | 193.562 | 225.784 | 222.153 | 245.421 |
| Current Budget | 189.062 | 219.765 | 216.408 | 220.918 |
| Total Adjustments | -4.500 | -6.019 | -5.745 | -24.503 |
| | | | | |
| Congressional program reductions | 0.000 | -6.019 | | |
| Congressional increases | 0.000 | 0.000 | | |
| Reprogrammings | -4.500 | 0.000 | | |
| SBIR/STTR transfer | 0.000 | 0.000 | | |

(U) Change Summary Explanation:

FY 2004 Decrease from reprogramming for Grand Challenge to Project AE-02.

FY 2005 Decrease reflects congressional program reduction for Space Based Networking and undistributed reductions.

FY 2006 Decrease reflects minor project repricing.

FY 2007 Decrease reflects phase down of Advanced Ground Tactical Battlefield Manager and Urban Commander programs in Project CCC-01; phase down of Next Generation (XG), Symbiotic Control and Optical & RF Combined Link Experiment (ORCLE) for planned transitions in the 2006/2007 timeframe; and reductions to classified programs in CCC-CLS.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Command, Control and Communications Systems PE 0603760E, Project CCC-01 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Command & Control Information Systems CCC-01 | 24.737 | 54.629 | 56.422 | 59.610 | 70.030 | 70.400 | 70.900 | 70.900 |

(U) Mission Description:

(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, Organically Assured and Survivable Information Systems (OASIS), and Active Templates (AcT).

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(U) Program Accomplishments/Planned Programs:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Joint Air/Ground Operations: Unified, Adaptive Replanning (JAGUAR) | 7.586 | 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 and weapons and communications relays. JAGUAR technology employs: 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 will produce ingress routes, flight schedules and patrol zones, while assuring airspace and electronic deconfliction. The technology will provide pilots and commanders the option to choose conventional tactics or conceive unconventional operations. In the latter case, the system will capture the innovation and retain the strategic maneuver for future mission plans. JAGUAR monitors actual plan execution against expected results and alerts commanders to significant differences. The technology will capture statistical descriptions of insignificant differences to help assess the robustness of future plans. The JAGUAR technology is planned for transition to the Air Force at the conclusion of Phase III anticipated to be completed 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Advanced Ground Tactical Battle Manager | 3.041 | 9.000 | 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.

(U) Program Plans:

- Develop an exercise environment with the Army Battle Command Battle Labs.
- Define interfaces to existing and future Army intelligence and command and control systems.
- Develop prototype tools to augment capability.
- Conduct experiments to ascertain the value of the tools.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|---------|---------|---------|---------|
| Predictive Battlespace Awareness | 2.000 | 6.034 | 4.046 | 3.258 |

(U) The Predictive Battlespace Awareness program is developing 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- 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

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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.

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------|---------|---------|---------|---------|
| Comprehensive Force Protection | 2.500 | 4.224 | 4.943 | 7.763 |

(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 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, attack threats.

(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.

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- 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 most to performance gaps.
- Demonstrate the final system in continuous operation at a CONUS base.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------|---------|---------|---------|---------|
| Urban Commander | 2.415 | 15.200 | 14.025 | 11.727 |

(U) The Urban Commander thrust will develop automated tools to help ground commanders construct detailed, realistic operational plans, particularly in nontraditional and urban environments. Partial plans will be represented in hierarchical task networks and visualized through synchronization matrices, icon overlays, or tactical sketch animations. Commanders and staff will 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 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 will continuously assess progress against the operational plan and alert users to significant deviations.

- The Urban Commander program is developing planning and control tools tailored to dismounted operations in complex urban environments. Urban warfare combines limited sightlines and mobility with insufficient knowledge of the disposition of enemy combatants, civilians, and the structures occupied. Urban Commander will form 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

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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.

- The Multi-spectral Adaptive Networked Tactical Imaging System (MANTIS) program is developing, integrating, and demonstrating a soldier-worn visualization system. The system consists of five elements: 1) helmet-mounted, multi-spectral sensor suite; 2) helmet-mounted, high resolution digital display; 3) helmet-mounted, 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 the signatures of imagery in three 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). MANTIS will regain the nighttime advantage for the individual warfighter in terms of mobility, situational awareness, and targeting. The system will also allow 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. In total, these technologies will furnish a larger field-of-view to enhance context. MANTIS will provide 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 will allow battlefield information to be overlaid on the display to provide augmented reality and increased situational awareness. MANTIS will interface with the future soldier’s advanced communications systems, allowing the warfighter to send/receive video images and position information with fellow soldiers and commanders in real time. MANTIS will also allow the soldier to receive images and information from remote sensors. 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 by FY 2006.

(U) Program Plans:

- Urban Commander.
 - Identify a set of urban combat scenarios ranging from peacekeeping to aggressive assault.
 - 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.
 - Construct an initial collection of operational plans, for many scenarios and force structures.
 - Develop tools to visualize, edit, modify, and assemble new plans from mixed-mode human interaction at one location.

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- Develop mechanisms to define and enforce policies limiting the aspects of a plan deemed relevant to each location.
 - Construct protocols to propagate changes generated at one location to affected locations, in accordance with defined policy.
 - 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.
 - Conduct a series of laboratory evaluations with Army and Marine commanders to assess the quality and utility of program products.
- 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.
 - Evaluate/demonstrate multi-sensor imagery and processing capability via MANTIS testbed.
 - Complete prototype design.
 - Deliver two MANTIS prototypes for evaluation.
 - Complete independent laboratory/field tests of MANTIS prototypes.
 - Transition to U.S. Army Future Soldier/Land Warrior via Future Force Warrior to Special Operations Forces and other transition partners.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Heterogenous Urban Reconnaissance Team (HURT) (formerly (C3RS)) | 0.000 | 9.235 | 11.157 | 15.782 |

(U) The Heterogeneous Urban Reconnaissance Team (HURT) initiative (formerly the Command and Control for CollaboRobotic Systems effort) will develop integrated tactical planning and battle management systems for heterogeneous collections of unmanned platforms operating in urban environments. HURT employs a model-based, control architecture, dynamic teaming and platform-independent command and control. The system registers new platforms with the battle manager (kinematics, maneuverability, endurance, payloads, and communications links) within the overall control model. HURT will provide a commander’s interface, which 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 could supply computationally intensive decision aids, such as advanced 4D airspace and groundspace deconfliction tools, route planners, and task/platform assignments algorithms. The

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technology will present mission status and future courses of action to commanders for collaborative adjudication. HURT will enable augmentation of low-footprint, rapidly deployable, easily sustainable human command structures with teams of machines operating together. HURT will define suitable roles for human command staffs charged with controlling squads of automated forces. The 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 III anticipated to be completed by FY 2007.

- (U) Program Plans:
- Select a baseline planning/control algorithm.
 - Develop hybrid state models.
 - 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Tactical Group Decision Analysis Support System | 0.000 | 0.000 | 2.853 | 4.591 |

(U) The Tactical Group Decision Analysis Support Systems program will develop distributed group decisions 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 controls systems.

- (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.

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- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------|---------|---------|---------|---------|
| OASIS | 5.227 | 0.000 | 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 policy; a framework for tolerating intrusions in large-scale, heterogeneous, networked computing enterprises; and 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 will transition 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 (JBI).
- Validated survivability claims of OASIS researchers technologies using recognized methodologies on operational systems.
- Demonstrated the effectiveness of survivable architectures in the face of a determined cyber attack on critical military information system.
- Evaluated and applied novel approaches to composing assurance cases for large-scale systems.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------|---------|---------|---------|---------|
| Active Templates (AcT) | 1.968 | 0.000 | 0.000 | 0.000 |

(U) The Active Templates (AcT) program produced robust, lightweight software technologies to improve Special Operations Forces mission planning and execution. Active Templates are distributed applications whose variables were linked to live data feeds and external problem-solving algorithms. AcT helped automate planning and execution by capturing, suggesting, and updating critical information, such as current state, goals, constraints, alternative actions, standard defaults, decisions in context and rationale. Active Templates were designed to be easily tailored, networked, noise-tolerant, user-supported, scalable, and widely adopted. AcT enabled special operations planners to create plans six times faster, improved plan quality by considering up to eight times more options, reduced staff-hours required to track and coordinate missions by 60 percent, and enhanced capture of lessons learned. This technology promises significantly improved national capability to respond in a crisis. Early prototypes of AcT technologies have been adopted and used by Special Operations Command (SOCOM), including use during Operation Enduring Freedom. There, they reduced plan development time by a factor of four and reduced personnel required for battle tracking by a factor of six. DARPA is working closely with the Joint Special Operations Command to develop temporal and spatial planning applications and simple forms-based coordination tools that may be defined dynamically by ordinary users in less than a day. Special Operations Command has approved a program for transitioning these technologies to the theater forces.

(U) Program Plans:

- Incorporated advanced problem solvers like generative planning, temporal/uncertain reasoning, and triggering for complex events.
- Demonstrated temporal, spatial, and forms-based mission planning and execution control tools.
- Measured their effectiveness in special operations exercises.
- Transitioned to U.S. Special Operations Command (SOCOM) and to all theater special operations commands.

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

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Information Integration Systems CCC-02 | 114.453 | 99.146 | 108.384 | 110.907 | 124.295 | 128.795 | 127.985 | 127.985 |

(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: 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), the Policy Based Network Management program, the Disruption Tolerant Networking program, the Network Centric Operations / Battle Command program, the Advanced Antenna Concepts program, the Navy Photonics program, the Advanced HF Communications program, the Communications to the Tactical Edge program, the Self-Forming Geographic Networks program, the Ideal RF Link program, the Robust, Responsive, Reconfigurable and Invisible (R3I) Network program and the Airborne Communications Node (ACN)/Adaptive Joint C4ISR Node Advanced Concept Technology Demonstrator (AJCN ACTD).

(U) Program Accomplishments/Planned Programs:

| | | | | |
|---------------------------------|----------------|----------------|----------------|----------------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Secure Adaptive Waveforms (SAW) | 7.146 | 7.800 | 4.013 | 6.753 |

(U) The Secure Adaptive Waveforms (SAW) program, and the related Polarized Rotation Modulation (PRZM) Communications program, will address lessons learned from the Airborne Communication Node (ACN) program concerning the need for secure communications waveforms. The SAW program will investigate approaches for an adaptive waveform agile communications system that can 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. New means of conducting secure communications are needed because the commercial availability of high performance RF components makes the basic tools necessary for conducting signals intelligence (SIGINT) exploitation available to our adversaries. It is realistic to assume that adversaries will soon have the capability and means to develop software exploitation techniques that make even the most advanced U. S. communications systems vulnerable. To defeat this threat, the technical goal is to identify approaches to eliminate repeatability in transmissions by adapting the waveform randomly and forcing random network routing.

(U) The goal of the Polarized Rotation Modulation (PRZM) Communications program is to develop new extremely high data rate, point-to-point, and wireless communications using the PRZM communications concept which can be implemented at any wavelength – RF to visible – to exploit the presently unused polarization and rotation dimensions of radiation. The PRZM 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
 - Initiate 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 test to validate PRZM concept.
 - Demonstrate at long range under operational conditions.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------|---------|---------|---------|---------|
| Connectionless Networking (CN) | 9.539 | 7.800 | 5.707 | 3.085 |

(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, in turn, 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 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 or updated weapons. Eliminating the requirement to maintain a continuous network linkage would enable these platforms to provide continuous connectivity without consumption of power, or compromising emanations. The CN program will exploit current 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 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.
- Develop and evaluate candidate approaches for implementation complexity, on-board processor and memory capability/power, overhead, scalability and performance.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------|---------|---------|---------|---------|
| Next Generation (XG) | 20.856 | 15.571 | 10.916 | 6.265 |

(U) The Next Generation (XG) program goals are to develop both the enabling technologies and system concepts to provide dramatic improvements in assured military communications in support of a full range of worldwide deployments through the dynamic redistribution of allocated spectrum along with novel waveforms. U.S. Forces face unique spectrum access issues in each country in which they operate, due to competing civilian or government users of national spectrum. These constraints must be reflected in all force planning and may preclude operation of critical systems. Coalition and allied operations are even more complex to manage, and may severely limit the U.S. ability to fully exploit its superiority and investment in information technology. The XG program approach is to develop the theoretical underpinnings for dynamic control of the spectrum, the technologies and subsystems that enable reallocation of the spectrum, and the system 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 Comms technology is planned for transition to the Army in the Joint Tactical Radio Systems clusters and is anticipated to be complete 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).
- Optimized correlation between distributed nodes.
- Investigate concepts for employment and utility of a dynamic waveform to the warfighter.
- Conduct lab demo of sense and adaptation technology performance.
- Perform analysis and simulation of multiple control protocols.
- Use military band spectrum analysis to assess subsystem technology development.
- Develop testbed for hardware in-the-loop testing of concepts.

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- Characterize next generation and RF component technology for inclusion into eventual demonstrator.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------|---------|---------|---------|---------|
| Advanced Speech Encoding (ASE) | 11.032 | 6.228 | 6.699 | 5.832 |

(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 (vocoders). 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 noise environments at 2400 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. An alternative approach explores the possibility of communication without acoustic information by extracting laryngeal and sublingual muscle signals that are produced when a person generates subvocal 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 and is anticipated to be completed by FY 2008.

(U) Program Plans:

- Demonstrated significant improvement in intelligibility and quality in harsh noise environments at 2400 bps.
- Demonstrate a voice communication system (sensors plus coder) operating at 1000 bits per second (bps) that is at least as good as that of today's DoD standard in harsh military noise environments.
- Demonstrate 300 bps vocoder with intelligibility, quality and aural speaker recognizability in harsh military noise environments that is at least as good as that of today's DoD standard.
- Demonstrate the capability for ultra-low-rate coding in a field demonstration of a prototype communications system.
- Characterize the nature of subvocalic signals (physiological source, speaker dependence, robustness) and the information content of the signals.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------|---------|---------|---------|---------|
| Symbiotic Communications | 22.440 | 12.726 | 8.738 | 2.259 |

(U) The Symbiotic Communications (SYCO) program will develop an airborne passive radar system to enable precision targeting and battlefield situational awareness. SYCO will generate, (1) High Resolution Terrain Information (HRTI), in real time, with accuracy at a minimum of Level 4 (as defined by the National Geospatial Intelligence Agency (NGA)) to enable precision targeting and situational awareness; (2) passive persistent Ground Moving Target Indication (GMTI) of very slow moving targets; and (3) 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. Further efforts will develop a prototype system capable of demonstrating a higher level of performance and will be packaged to be capable of deployment in a C-130 aircraft. The SYCO technology is planned for transition to the Air Force in FY 2007.

- (U) Program Plans:
- Demonstrate automated algorithms to enable real-time processing.
 - Develop real-time airborne demonstrator system.
 - Demonstrate HRTI Level 4 with real-time processing of flight data.
 - Demonstrate real-time GMTI of very slow movers.
 - Participate in limited user testing.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Optical & RF Combined Link Experiment (ORCLE) | 38.541 | 24.519 | 21.041 | 3.791 |

(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, atmospheric and aero-optics to provide the joint force

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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 by late FY 2006/early FY 2007.

(U) Program Plans:

- Develop 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.
- Develop 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Policy Based Network Management (PBNM) | 0.000 | 2.000 | 4.599 | 6.457 |

(U) Drawing upon lessons learned from the 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. The Policy Based Network Management technology is planned for transition to the Army in FY 2008.

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- (U) Program Plans:
- Develop robust, secure self-forming tactical networks able to be dynamically changed based on the commander's strategic and operational mission objectives.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------------|---------|---------|---------|---------|
| Disruption Tolerant Networking (DTN) | 0.000 | 7.100 | 6.633 | 10.511 |

(U) Drawing upon technical challenges identified in specific programs such as ACN/AJCN and other non-ground based Mobile Ad-Hoc Network (MANET) programs, the Disruption Tolerant Networking (DTN) will develop network protocols 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. DARPA will develop the specifications, engage the military, commercial and the Internet communities to maximize the applicability and commercial viability of these protocols, and develop the basic software in an open source mode. DARPA will then implement these protocols 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 by the network.
 - 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Network Centric Operations/Battle Command | 0.000 | 7.500 | 9.054 | 12.296 |

(U) The DoD is transforming to a more network centric focus for military operations, e.g., FORCENet, Joint Battlespace Infosphere, and Future Combat Systems/Unit of Action (UA). Until recently, the primary technological emphasis has been oriented towards improving Command, Control, Communications and Computing, Intelligence, Surveillance and Reconnaissance (C4ISR) systems to enable better sensor-decider-shooter linkages. To be more effective in joint operations, network centricity development must receive equal priority to facilitate battlefield understanding to the commanders at all echelons, in a form best suited for their information assimilation (receptive) and decision processes (intuitive). In other words, network centricity must improve the art of battle command, rather than just the science of C4ISR, to be a force multiplier. This new initiative will develop and demonstrate the enabling technologies for Network Centric Operations, with emphasis on creating understanding for battle command. It will seamlessly connect the Network Centric Enterprise and Network Centric Warfare layers through understanding, thereby enabling shared awareness, collaboration and self-synchronization among the various joint components and echelons. This program integrates technologies enabling secure, assured, multi-subscriber, multi-purpose (e.g., maneuver, logistics, intelligence) networks with commander-centric command and control/intelligence technologies, including forecasting/prediction of Courses of Action (COA) and sustainment tools, into one unified joint battle command system. It will allow the Strategic/Operational Commanders to simultaneously orchestrate and coordinate the deployment, combat operations and resourcing of multiple UAs supported by multi-service, interagency, multinational and nongovernmental activities. It will also support long range indirect fire support and effects, persistent theater Intelligence Surveillance Reconnaissance (ISR), and continuous sustainment. For example, results of this program could help the Army produce within 30 minutes, with a quality equivalent to what could be produced by a staff of senior planners with no time limit, (1) Running start insertion plan for multiple UAs; (2) transition plan for 3 UAs to maintain tempo in multiple battles; and (3) Operational maneuver of a UA by strategic air lift. Future capabilities include, but are not limited to: Network Centric Operations, including Enterprise and Warfare layers; synergistic battle command among all joint components and echelons; networked manned and unmanned systems; cognitive systems; and robust, secure self-forming tactical networks seamlessly connected to the Global Information Grid (GIG). Initial technologies developed in the program will transition to the Army Unit of Employment and the U.S. Joint Forces Command as a basal capability in FY 2006, with more comprehensive capabilities transitioning in FY 2008 and FY 2009.

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(U) Program Plans:

- Develop and demonstrate a single common architecture and common technology building blocks for seamlessly integrating the Strategic, Operational and Tactical levels of warfare.
- Research and demonstrate new protocols for mobile ad hoc network (MANET)-type self-forming, ad hoc, tactical networks incorporating low probabilities of detection and intercepts (LPD/LPI), spectrum efficient waveforms; advanced information assurance; and unmanned air vehicle (UAV) gateways.
- Develop interface systems for seamlessly integrating data from MANET-type self-forming, ad hoc, tactical networks into high data rate internet-type networks like the GIG.
- Develop a military unique version of Code Division Multiple Access (CDMA) spread spectrum communications that may leverage commercial advancements in CDMA for the physical and media access control (MAC) layers.
- Develop methods for creating running estimates of operations and sustainment.
- Develop and demonstrate technologies for integrating prediction/forecasting techniques into COA generation and real-time war gaming for understanding.
- Develop commander-machine interfaces, including receptive graphics generators, to facilitate intuitive decision making.
- Investigate e-commerce logistics techniques for application to battle space sustainment.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Advanced Antenna Concepts | 0.000 | 4.152 | 5.711 | 7.068 |

(U) The Adaptive Amplification to Enable Electrically Small Antennas effort (formerly known as the Micro-Aperture Circuit effort) will develop and implement advanced circuit theory (non-Foster matching) that will enable electrically short antennas to be used with similar effectiveness to larger ones, and to dynamically match antennas throughout a wide range of frequencies. 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 frequencies (High Frequency) very suitable 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 (wide-band gap materials) offers the ability to fabricate devices that can effectively couple to very non-resonant antennas. In this program DARPA will develop the basic technology, and then apply it to develop radios with wide bands of operation and very small physical size. Approaches will include building amplifiers that operate under highly reactive loads and the leveraging of new junctions and amplifier modes for increased

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performance. A potential application will be a self-contained cell phone size device that can use High Frequency (HF) to communicate around the world without any infrastructure. The Adaptive Amplification to Enable Electrically Small Antennas technology is planned for transition to the Army (primary), Navy and Air Force (secondary) in FY 2009.

(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 by interconnecting the receive elements to transmit elements in a conjugate (“van-Atta”) fashion. The idea is the combining and tailoring of noise-correlating interferometry and retro-directive antenna arrays into retro-directive noise-correlating (RNC) radar. The combination of these innovations allows the radar to operate in omni-directional search mode by broadcasting white noise over a specified search angle determined by the beam pattern of the individual elements. Once a target of adequate cross section enters the beam within the range of the sensor, correlations appear in the noise between neighboring antennas. The received noise power is then amplified by the transceiver electronic chain and re-transmitted directly towards the target in a process call the RNC feedback loop. 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 to Enable Electrically Small Antennas
 - Develop negative inductors and capacitors in both grounded and floating configurations.
 - Show that non-foster coupling allows order-of-magnitude decrease in cavity volume and antenna length.
 - Demonstrate improved communications on small and low-observable platforms.
 - Demonstrate better power efficiency with non-foster matching.
 - Design, build, and demonstrate a non-foster matching circuit amplifier to deliver 5W or more to an electrically-small antenna.

- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------|---------|---------|---------|---------|
| Navy Photonics Program | 0.000 | 3.750 | 4.000 | 2.750 |

(U) The Navy Photonics Program will develop and field technology in partnership with the Naval Air Systems Command (NAVAIR) Program Executive Office (Tactical Aircraft Programs) (PEO (T)) in a rapid research, development, and demonstration project. This effort will pursue opto-electronic integration of state-of-the art radio frequency (RF) and digital photonics, RF and digital integrated circuits and micro-electro-mechanics (MEMS) technologies for embedded aerospace applications. The photonics technology from this effort will result in the development of a common optical backbone in place of many point-to-point links. The DARPA portion of the Navy Photonics Program will address high-risk development areas including reduction of fiber optic device size. As a result, this size reduction will enable placement of components in currently inaccessible locations (i.e., beyond the wing-fold). This program should result in a tighter integration of optical components with a decrease in unit size, increased reliability and decreased production costs. Based on the results of the risk reduction and accomplishments of this program, the goal is the operational transition into the Navy EA-6B Prowler and other tactical aircraft (i.e. EA-18, EA-35, E-2C, and MMA). DARPA established an MOA with the Navy Tactical Aircraft Program Office for this program. The Navy Photonics technology is planned for transition to the Navy by FY 2008.

(U) Program Plans:

- Develop a fiber optic backbone network capable of interconnecting to the transmitter side of an electronic aircraft podded jamming system.
- Design optical components that will meet the volume, weight, and environmental specifications for an airborne platform.
- Integrate and reduce the size of the technology to allow the external optical interfaces to be positioned inside the electronic warfare equipment space.
- Perform flight demonstrations showing the use of the fiber optical backbone interconnected to the electronic attack aircraft jamming systems.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------|---------|---------|---------|---------|
| Advanced HF Communications | 0.000 | 0.000 | 1.842 | 5.472 |

(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. 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 requirements for SOF applicability. Novel miniature HF antenna technologies and channel adaptive radio technologies will be developed and demonstrated in man portable form factors.

(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 dual mode transceiver prototype in a package that validates the size, weight and power requirements of the SOF user.
- Perform field demonstration on prototype transceiver in various environments to validate the concept.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------------|---------|---------|---------|---------|
| Communications to the Tactical Edge | 0.000 | 0.000 | 4.375 | 9.062 |

(U) The future DoD communications architecture will provide a multi-tiered capability consisting of a worldwide, broadband Global Information Grid (GIG), transportable nets 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 network of networks is “user-ignorant”; it only transports packets or sets up voice circuits, and does so on a “best-effort” basis. It puts the burden on the mobile users at the edge to find

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connections and join a “user-ignorant” network. This project will provide technology to make networks “user-aware” and oriented toward delivering tailored services to each user by balancing communications supply and demand. Rather than provide “best effort” with no guarantees, the network will provide “best service” with guarantees. The key challenge is providing services to disadvantaged users for whom demand exceeds supply.

- (U) Program Plans:
- Develop technology to implement a user-transparent service layer that monitors the communications supply and demand at each user (or end system) and is aware of the military missions being executed by each user.
 - Develop middleware technology to modulate demands to meet supply by means such as context-preserving “compression” and filtering.
 - Develop protocols to find and form relationships across diverse networks and proactively adapt transport flow and quality to the available links by management of network topology vice ad hoc networking.
 - Perform trial demonstrations using simulation and emulation over existing backbone networks.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------|---------|---------|---------|---------|
| Self-Forming Networks | 0.000 | 0.000 | 4.606 | 7.929 |

(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.

- (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.

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- 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------|---------|---------|---------|---------|
| Ideal RF Link | 0.000 | 0.000 | 5.370 | 9.499 |

(U) The Ideal RF Link program 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 RF components. The effort will develop new circuit topologies and algorithms along with cross technology integrations schemes. The 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 communications 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Robust, Responsive, Reconfigurable and Invisible (R3I) Network | 0.000 | 0.000 | 5.080 | 11.878 |

(U) The Robust, Responsive, Reconfigurable and Invisible (R3I) Network 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

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infrastructure. This program will develop the essential network structure to enable robust, mobile, tactical wireless networks, which are the foundation for the Global Information Grid and network centric warfare concepts. The fundamental technical challenges are scalability, covertness, robustness and platform size, weight and power requirements.

- (U) Program Plans:
- Develop the waveform and access protocols necessary to meet capacity and availability requirements.
 - Explore new areas of information theory to investigate more robust routing algorithms and protocols.
 - Expand existing dynamic planning software to ensure connectivity between users based on mission needs and resource availability with respect to tactically relevant time constraints.
 - Validate system performance through a combination of simulation and hardware prototype field demonstrations.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------------|---------|---------|---------|---------|
| Airborne Comms Node (ACN)/AJCN ACTD | 4.899 | 0.000 | 0.000 | 0.000 |

(U) The Airborne Communications Node (ACN) program enabled an affordable, autonomous communications infrastructure that simultaneously provides assured communications, situational awareness and signals intelligence (SIGINT). ACN payloads can be integrated on platforms ranging from High Altitude Endurance (HAE) unmanned airborne platforms (e.g., Global Hawk) to vessels or ground vehicles. The ACN system operational utility will be assessed by U.S. Joint Forces Command as part of a Joint Advanced Concept Technology Demonstrations (ACTD), named the Adaptive Joint C4ISR Node (AJCN) that began in FY 2003 and will complete in FY 2005 with an extended user evaluation in FY2006 – FY2007. The ACTD, jointly funded by Memorandum of Agreement between DARPA, Army, Air Force, U.S. Joint Forces Command, and the Office of the Secretary of Defense, will integrate ACN payloads onboard Air Force and Army aircraft. Additionally, in response to Operation Iraqi Freedom, DARPA is developing a simplified version of the Airborne Comms Node that will be deployed from an aerostat to provide communication coverage for remotely located U. S. troops. Transition of the program has been accomplished by the ACTD and the Marine Airborne Relay Terminal programs.

- (U) Program Plans:
- Conducted a flight demonstration lab payload and began integration of the flight payload that will be used for the Interim Joint Military Utility Assessment (IJMUA).

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- Integrated a Joint Tactical Radio Systems (JTRS) Software Component Architecture (SCA) 2.2 Core Framework and showed the ability to run software waveforms using that SCA implementation.
- Integrated AJCN payload and antennas on C-23 aircraft and conducted an Interim Joint Military Utility Assessment (IJMUA) of multi-mission functionality.
- Conducted flight test on C-23 to evaluate in-flight co-site mitigation performance.
- Integrated JTRS (Single Channel Ground Air Radio System) SINCGARS waveform within AJCN architecture to demonstrate feasibility of porting JTRS waveforms.
- Initiated development of Concept of Operations, Tactics, Techniques and Procedures (TTP), and training package.
- Investigated technologies to provide secure waveforms.
- Investigated technologies to incorporate other systems (such as UGS) into the ACN architecture.
- Investigated technologies for advanced networking concepts, especially between dissimilar platforms.
- Integrated AJCN payloads on 2 Hunters and 2 NKC-135s.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 80.961 | 62.546 | 139.100 | 66.900 | 62.500 | 63.000 | 66.000 | 68.000 |
| Rapid Strike Force Technology LNW-01 | 14.154 | 0.721 | 36.400 | 46.400 | 47.630 | 60.120 | 66.000 | 68.000 |
| Small Unit Operations LNW-02 | 12.757 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Future Combat Systems LNW-03 | 54.050 | 61.825 | 102.700 | 20.500 | 14.870 | 2.880 | 0.000 | 0.000 |

(U) Mission Description:

(U) This program element is budgeted in the Advanced Technology Development Budget Activity because it is developing and demonstrating the concepts and technologies that will address the mission requirements of the 21st Century land warrior.

(U) The emerging U.S. vision of future land warfare places strong emphasis on technology supporting early entry of light, efficient land forces. This project is developing technologies that enable mobile and survivable systems for efficient command and control, mobility, surveillance, targeting and reconnaissance as well as effective and adaptive weaponry, which are important aspects of an early-entry capability. The project consists of: Mach 5/50 Technology Development; Boomerang; Multi-Modal Missile; Non-Lethal Alternatives for Urban Operations; and the Tactical Urban Operations program. These programs are closely coordinated with the U.S. Army, Navy and Marine Corps.

(U) The U.S. Military requires flexible, effective and efficient multi-mission forces capable of projecting overwhelming military power worldwide. This force must ultimately provide our national leaders with increased options when responding to potential crises and conflicts. To satisfy this requirement, the joint Army/DARPA Future Combat Systems (FCS) program is being developed to provide enhancements in land force lethality, protection, mobility, deployability, sustainability, and command and control capabilities.

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|------------|--|-----------------------|-----------------------|----------------------|----------------------|
| (U) | <u>Program Change Summary:</u> <i>(In Millions)</i> | <u>FY 2004</u> | <u>FY 2005</u> | <u>FY2006</u> | <u>FY2007</u> |
| | Previous President's Budget | 81.513 | 63.121 | 102.700 | 55.000 |
| | Current Budget | 80.961 | 62.546 | 139.100 | 66.900 |
| | Total Adjustments | -0.552 | -0.575 | 36.400 | 11.900 |
| | Congressional program reductions | 0.000 | -0.575 | | |
| | Congressional increases | 0.000 | 0.000 | | |
| | Reprogrammings | 0.900 | 0.000 | | |
| | SBIR/STTR transfer | -1.452 | 0.000 | | |

- (U) Change Summary Explanation:**
- FY 2004 Decrease reflects SBIR/STTR transfer and a below threshold reprogramming.
 - FY 2005 Decrease reflects congressional undistributed reductions.
 - FY 2006 - 2007 Increase reflects additional funds in project LNW-01 to fund new non-lethal technologies and tactical urban operations efforts.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Rapid Strike Force Technology LNW-01 | 14.154 | 0.721 | 36.400 | 46.400 | 47.630 | 60.120 | 66.000 | 68.000 |

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
| Mach 5/50 Technology Development | 1.219 | 0.000 | 0.000 | 0.000 |

(U) Previously completed tasks in this project demonstrated revolutionary weapon concepts for firing small caliber projectiles at very high rates without the need for internal moving parts. The continuing Mach 5/50 tasks extend the concepts and technologies for leap-ahead performance in tactically relevant, lightweight, medium caliber direct fire weapons. The medium caliber projectiles (50-60 millimeter, 728 grams) will have a minimum muzzle velocity of 1,600 meters per second (~ Mach 5) at 600 rounds per minute or greater. Mach 5/50 technology development will provide multiple Services with a low-cost, reliable enabling technology to support a wide range of current and future applications including extended range combat vehicle firepower and lethality, full-spectrum future combat vehicle lethality for active protection systems, high engagement rate naval air defense, critical fixed site defense and improved aircraft self-defense. Portions of the technology development are conducted under an agreement with the Australian Defence Science and Technology Office.

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(U) Program Plans:

- Develop medium caliber concepts, detailed performance simulations and technical analyses.
- Fabricate and test critical technology subsystems.
- Complete integration of pre-prototype components and evaluate against simulation-based interim performance parameters.
- Critical design review and complete fabrication of full-function prototype.
- Complete system test and evaluation of full function prototype and validate simulations.
- Conduct Phase 1 firing demonstration and deliver final report.
- Conduct Phase 1 Rate of Fire demonstration.
- Transition hardware and data packages to DoD laboratories for Service-specific engineering and platform integration.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------|---------|---------|---------|---------|
| Boomerang | 5.483 | 0.721 | 0.000 | 0.000 |

(U) This program continued work previously reported under PE 0602702E, Tactical Technology to rapidly develop and demonstrate affordable and reliable acoustic gun shot detection and localization techniques. This program focused on enhancing the safety of vehicle convoys and increasing situational awareness. Based on previous acoustic shot detection work, this program 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 are being tested by warfighters serving in Operation Iraqi Freedom (OIF) and are providing force protection capabilities for moving vehicles and stationary sites. 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 stationary and moving targets. Comments from deployed troops continue to be collected and analyzed. As a result, an improved version of the Boomerang system with significantly smaller acoustic arrays (designed to reduce visual footprint) is being 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.

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- (U) Program Plans:
- Improve performance based on data from deployed systems, user feedback and evolving concepts of operations.
 - Conduct extensive testing on the enhanced system to validate improved system performance, reliability, and robustness.
 - Fabricate and deliver updated systems to deployed warfighters for field testing.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------|---------|---------|---------|---------|
| Multi-Modal Missile | 0.000 | 0.000 | 12.400 | 16.400 |

(U) The Multi Modal Missile 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) the potential for 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 and will consider beyond-line-of-sight functionality. 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Non-Lethal Alternatives for Urban Operations | 0.000 | 0.000 | 12.000 | 15.000 |

(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 counter effects, and will develop integrated less-lethal system options for application to urban warfighting. Effects to be investigated will include less-lethal projectiles, malodorants, counter mobility agents, entanglers, and marking agents. The effort will address both systems designed to counter individual personnel and systems designed to provide area effects against vehicles, crowds and groups of combatants. This effort will explore both direct fire and indirect fire delivery options. Systems concepts to be explored will include force protection for fixed sites, force protection for mobile forces, individual soldier weapon options, systems for border protection, systems for protection of extended infrastructure and systems to support application on autonomous and teleoperated unmanned ground robotic vehicles in urban environments.

(U) Program Plans:

- Perform initial concept development and effects assessment.
- Develop initial urban less-lethal system design.
- Begin focused less-than-lethal technology maturation efforts to address and reduce system risk.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Tactical Urban Operations (TURBO) program | 0.000 | 0.000 | 12.000 | 15.000 |

(U) The Tactical Urban Operations (TURBO) program is an outgrowth of the Precision Urban Combat System (PUCS) program funded from PE 0603766E, Project NET-01. TURBO will develop and validate advanced precision and area weapon capabilities for use by joint dismounted forces in urban combat operations. Example technologies include: precision munitions with greatly improved accuracies, individual area effect munitions with greater range and flexibility, sensors with the capability to detect hidden human targets, improved weapon sights and weapon enhancements to provide greater accuracy and identification of friend or foe, multi spectral designation / marking systems for improved flexibility and covertness, and robotic applications. These systems will be developed within the framework of both legacy forces and expected future forces.

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The result will be to provide dismounted soldiers with increased capability and flexibility, and to move precision munitions accuracies from meters to centimeters thus allowing very small weapons to be effectively employed. 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 PUCS system.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Reconnaissance, Surveillance and Targeting Vehicle (RST-V) | 7.452 | 0.000 | 0.000 | 0.000 |

(U) The Reconnaissance, Surveillance and Targeting Vehicle (RST-V) program, conducted by the Marine Corps and DARPA, designed, developed, and demonstrated a prototype hybrid electric drive, lightweight, highly maneuverable advanced technology demonstrator vehicle capable of V-22 internal transport. The vehicle incorporated technological advancements in the areas of integrated survivability techniques and advanced suspension. The vehicle also hosts integrated precision geolocation, communication and Reconnaissance, Surveillance and Targeting sensor subsystems. The RST-V platform provides a mobile quick deployment and deep insertion capable, multi-sensor, battlespace awareness asset for small unit tactical reconnaissance teams, fire support coordinators and special reconnaissance forces. Continuing efforts were funded to accelerate the prototype into Technology Readiness Level (TRL) 6 with hardening of components prior to the system development phase and full transition to the Marine Corps. DARPA established an MOA with the Marine Corps for final transition of this program in September 2004.

- (U) Program Plans:
- Funded component upgrades to reach TRL 6 and transition to Marine Corps.

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

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Future Combat Systems LNW-03 | 54.050 | 61.825 | 102.700 | 20.500 | 14.870 | 2.880 | 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 2004 | FY 2005 | FY 2006 | FY 2007 |
| FCS Supporting Technologies | 54.050 | 61.825 | 102.700 | 20.500 |

(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.

(U) The Perception for Off-road Robotics (PerceptOR) program identified and developed revolutionary unmanned vehicle perception prototypes. These perception systems were flexible enough to operate in off-road environments and provided extensive experimental test data in a variety of operationally relevant terrain and weather conditions. The resulting technology is applicable to a variety of combat roles and will enable

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greater confidence in postulating the conditions under which unmanned off-road robotics should be used. The FCS PerceptOR technology was integrated into the UGCV-PerceptOR Integration (UPI) program.

(U) The Unmanned Ground Combat Vehicle (UGV) program developed vehicle prototypes exhibiting advanced performance in endurance, obstacle negotiation, and transportability (small size) based on novel designs unrestrained by the need to accommodate human crews. These prototypes included unique mobility configurations, exceptional drivetrains, advanced structures/composites, terrain/soil analysis, sensory exploitation and interaction with robotic control architectures. The FCS UGSV technology was integrated into the UGCV-PerceptOR Integration (UPI) program.

(U) The UGCV-PerceptOR Integration (UPI) program will integrate autonomous navigation algorithms with the Spinner platform to yield an unmanned ground vehicle (UGV) that operates reliably in obstacle-rich terrain. Spinners will be used as platforms to port and test methods for perception techniques to optimize autonomous performance. This natural mating of the best-of-class sensors and algorithms on a vehicle of Spinner's class represents a leap forward in UGV capability. Autonomous mobility will be further enhanced by the use of terrain data for path planning. The program's technologies will transfer to the FCS Armed Robotic Vehicle (ARV) and Autonomous Navigation System (ANS) programs through PM-UA, 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 Multi Cell Command and Control technology is planned for transition to the Army at the conclusion of Phase II, anticipated to be completed by FY 2006.

(U) The Maneuver C³ 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 (C²) operators. The

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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 C² 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 C² architecture and large support staffs. DARPA established an MOA with the Army for this program in July 2004.

(U) Under the Maneuver C³ 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, FCS Program at the conclusion of Phase II that is anticipated to be completed by FY 2007.

(U) The Netfires program developed and tested a containerized, platform-independent multi-mission weapon concept as an enabling technology element for FCS. NetFires provides rapid response and lethality in packages requiring significantly fewer personnel, decreased logistical support and lower life-cycle costs, while increasing survivability compared to current direct fire gun and missile artillery. NetFires will allow FCS to defeat all known threats, will be air deployable in C-130 (and smaller) aircraft, and will enhance the situation awareness and survivability of FCS by providing standoff target acquisition and extended-range, non-line-of-sight engagements. The program developed and demonstrated a highly flexible modular, multimission precision missile and a loitering attack missile that can be remotely commanded. Both missile types have a self-locating launcher and a command and control system compatible with FCS. This program transitioned to the Army in March 2004.

(U) Two autonomous air vehicle programs will provide reconnaissance and surveillance, and targetin g 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

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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 consists of 2 primary elements: development of lift augmented ducted fan vertical flight vehicles together with their associated flight controls; and evaluation and integration of supporting technologies including non-line-of-sight communications, heavy fuel engines, improved navigation and obstacle avoidance, and acoustic noise reduction. Once the basic flight vehicle is proven, these technologies will be integrated into the flight vehicle and demonstrated in a simulated mission. 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 to be developed in FY 2005 will be no greater than 112 lbs. DARPA established an MOA with the Army for this program in December 2004. 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. It 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 warfighting environments (for example: in complex topologies such as mountainous terrain; urban areas; confined spaces; and high concentrations of civilians). 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, VTOL UAVs rapidly into the hands of the users for evaluation and evolution of the technologies; development of 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 develops advanced laser radar (LADAR) sensor systems and technologies. Jigsaw enables warfighters to accomplish day/night target identification and verification in stressing environments. Environments of interest include targets hidden by foliage and camouflage, and targets in urban settings, such as alleyways. Jigsaw technologies are designed to provide

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warfighters with reliable combat identification; the LADAR sensor will deliver a visual picture of the target scene. DARPA established an MOA with the Night Vision and Electronic Sensors Directorate for this program in October 2004. The JIGSAW technology is planned for transition to the Army at the conclusion of Phase III that 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 enemy combat vehicles and dismounted troops moving in open and forested areas of the battlefield. The technology allows Objective Force commanders to operate with confidence in forested areas. It also detects low-flying aircraft such as helicopters and ultra-lights. Its synthetic aperture radar images support terrain delimitation, road identification, and target tracking in wooded areas. FORESTER is a UHF-band FOPEN GMTI radar for deployment on rotary wing platforms such as the A160 unmanned helicopter. The radar, operating from a hovering platform under calm wind conditions, can achieve calm-weather detection ranges in excess of 30 kilometers against dismounted troops moving in forested areas. The program employs adaptive antenna 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 Affordable Adaptive Conformal Electronically Steerable Array Radar (AACER) program develops components and technologies for a helicopter-borne surveillance, targeting, and communications capability and integrates them into an airborne system suitable for use on the next generation Unmanned Airborne Vehicles such as A-160. The technologies being developed include: (1) Ka band Electronically Scanned Antenna Arrays (ESA) which lend themselves to affordable manufacturing techniques; (2) underlying ESA devices such as phase shifting elements and power amplifiers/combiners which operate at Ka band and are affordable yet support the requirements of a high performance radar system; (3) miniature receiver exciter modules capable of generating waveforms for high performance MTI and SAR radar, for communications functions including combat identification, and for growth to higher performance and additional functions in radar and electronic warfare; (4) very high performance, small size and low cost signal processors to support high resolution radar surveillance and tracking functions, target imaging and geolocation, and communications functions; (5) signal processing algorithms to optimally exploit the inherent capability of the ESA to support multiple functions simultaneously, each with state-of-the-art operational performance; and (6) integration of all technical elements into a functional system that meets UAV platform constraints, is suitable for flight demonstration on manned and unmanned vehicles, and provides a concrete basis for demonstrating the affordability of production units. If successful, this program will provide a vastly improved intelligence and targeting capability for local commanders by providing a dedicated, rapidly taskable asset with the capability to maintain surveillance of a large

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region of their battlespace, including areas inaccessible or obscured to larger airborne assets. DARPA established an MOA with the Army for this program in January 2005. The AACER technology is planned for transition to the PEO-I EW at the conclusion of Phase III, anticipated to be completed by FY 2008.

(U) The Affordable Weapon System Long Gun program will evaluate and develop a re-useable, long endurance, low cost, joint, unmanned/armed missile system combined with a tri-mode long wave infrared/near infrared/visible (LWIR/NIR/VIS) sensor with laser spot targeting. Ducted fan propulsion will provide efficient thrust for long endurance. The missile will be launched from a canister carried on a sea or ground vehicle, will fly to a specified target area, and use a tri-mode sensor operating at visible, long, and near-infrared wavelengths to search for targets. If a qualified target is found, the missile will attack the target with a self-contained munition. If no targets are found, the missile could be commanded to return to base. The missile will include a data link back to a human controller/operator to confirm target characteristics, approve engagement, and perform battle damage assessment. Beginning in FY 2005, the program is funded under PE 0603286E, Project AIR-01.

(U) The electro-magnetic (EM) Mortar program will design and demonstrate EM guns (coilgun and railgun) capable of firing modified 120 mm mortar rounds to 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 operational capability will be accomplished through the Army FCS program, and is anticipated to occur in FY 2007.

(U) The DP-5X program will provide a flight-ready, tactically transportable, vertical take-off and landing unmanned air vehicle (VTOL UAV) to integrate with a gimbaled payload for technology demonstration of the JIGSAW sensor package. The UAV will be employable by a two person team and deployable in a single HMMWV. It will provide lift for a 75 lb payload with 6 hours endurance, 100 kts cruising speed, with nap of the earth agility. Multi-mission capability and modularity will allow the DP-5X to rapidly integrate additional payloads for sensing, communications, and target effects. The DP-5X program is planned for transition to the Army in FY 2007.

(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

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TRADOC “Future’s Center.” The project has three initial focus areas: Air Assault Expeditionary Forces (AAEF), USMA Systems Engineering, and Directed Studies.

(U) The objective of the FCS International Cooperation program is to establish a Science and Technology Project Agreement with Singapore as well as supporting the conduct of FY 2004 Coalition Interoperability wargaming analysis with Singapore and the UK using the DARPA developed Joint Semi Automated Forces (JSAF) Simulation. The program is in collaboration with the Army. The Singapore Project agreement will initially support the Mechanized Air Assault, Unmanned Air Vehicles, Coalition Command and Control, and Multispectral Goggles for Dismounted Infantrymen and Scouts. This program investigates the development of novel quantum dot detector technology and applications to multi-spectral systems, concentrating on the visible to near infrared. The initial assessment of detector technology will include the spectral sensitivity, quantum yield and temperature-dependant material parameters. These parameters will be related to the sensor requirements, including new design concepts for unique micro-sensors and goggle applications. DARPA established an MOA with the Army for this program in April 2004. The FCS International Cooperation technology is planned for transition to the Army by FY 2007.

(U) The Sensor DART program will produce and demonstrate unattended ground sensors into an aerodynamic glider capable of covert delivery from a stand-off at least 45 km with a 50 m or less circular error probability (CEP). Sensor DART will leverage and integrate capabilities derived from the Hawkeye small UAV demonstrator and Steel Rattler (hand emplaced) and Steel Eagle (F-15 air emplaced) 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 Unit of Action (UA). The transition customer will be UA Product Manager Robotic and Unmanned Sensors (PM RUS) out of Fort Monmouth. Transition will 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 by FY 2006.

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- (U) Program Plans:
- PerceptOR
 - Conducted perception system prototype development testing in both laboratory and field.
 - Conducted evaluation experiments on early perception system prototypes in variety of terrain and environmental conditions.
 - Conducted algorithm development for advanced perception behavior.
 - Continued algorithm and supporting technology developments for unmanned maneuver.
 - Updated prototype algorithms and hardware based on supporting experimentation.
 - Explored system implications of degraded component performance (communications constraints, sensor and other faults).
 - Unmanned Ground Combat Vehicle (UGCV)
 - Conducted UGCV surrogate tests.
 - Conducted testing of prototypes against mobility, endurance, and payload fraction metrics.
 - Conducted resilience testing on prototypes and make reliability measurements.
 - Updated prototype hardware with late development technology and prepare for extreme testing conditions.
 - UGCV – PerceptOR Integration (UPI)
 - Integrate perception on original Spinner.
 - Redesign and construct (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.

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- Maneuver C³
 - Validate organic, self-contained approaches versus approaches that “reachback” to other systems for C².
 - 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.
 - Conduct experiments in support of selected command and control functions for operations with manned/unmanned systems.
 - Complete the development of an initial C² experimental demonstrator.
 - Continue experiments of Unit Cell C² incorporating limited activities of the dismounted soldier.
 - Extend C² 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)
 - Validate 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.

- Netfires
 - Program transitioned to Army in FY 2004.

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- Organic Air Vehicle - II
 - Initiate competitive contracts for system preliminary design.
 - Evaluate preliminary designs and downselect to best design(s).
 - Perform detailed designs of flight vehicles.
 - Perform risk reduction testing on critical vehicle subsystems.
 - Develop ~ 112 lb (dry weight) flight vehicle and demonstrate robust flight stability.
 - 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 transition T-MAV (gasoline engine) in military operations in urban terrain exercises and conduct experiments with troops in field trials.
 - Develop small heavy fuel engines.
 - Demonstrate diesel D-MAV (diesel engine) in military operations in urban terrain exercises and conduct experiments with troops in field trials.
 - Provide Army unit from 25th Infantry Division, 25 D-MAV systems (50 air Vehicles) as a residual operational capability.

- Jigsaw Phase III
 - Establish a Joint DARPA-NVESD (U. S. Army Night Vision and Electronic Sensors Directorate) JIGSAW Program.
 - Develop a form, fit, & function Jigsaw Sensor for integration onto the DP-5X.
 - Develop real-time on-board registration and processing capability.
 - 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.

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- Conduct end-to-end system performance tests that include aircraft effects under static and dynamic conditions.
- Conduct airborne flight-testing and demonstrate performance with the fully integrated FORESTER/aircraft system.

- Affordable Adaptive Conformal Electronically Steerable Array Radar (AACER)
 - Initiate competitive contracts for system preliminary design.
 - Evaluate preliminary system designs, production cost estimates, and results from critical antenna technology demonstrations and down select to best design(s).
 - Develop prototype modules and perform subsystem tests, system integration, and rooftop testing.
 - Perform flight tests, system characterization, and simulated military missions in manned aircraft, and finalize production cost estimates.
 - Modify designs/software based on flight test results, and integrate to unmanned air vehicle.
 - Train military operators and perform simulated military mission tests and evaluation.

- Long Gun System
 - Modify existing Affordable Weapon System (AWS) airframe as basis for missile design.
 - Replace engine with ducted fan with rotary engine operated with heavy fuel.

- EM Mortar
 - Conduct modeling and simulation to design the launcher, power supply, and projectile modifications for coupling to the launcher.
 - Design launcher for mortar launch application and develop 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
 - Design and fabricate airframe.

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- Test DP-5X rotor.
- Integrate airframe with automatic controls.
- Conduct airframe thermal and vibration testing.
- Integrate sensor package with airframe.
- Conduct flight tests of airframe with 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 concepts of operations through enabling technologies.
 - Evaluate the operational performance of the DARPA Organic and Micro Air Vehicles in complex terrain environments, e.g. urban and jungle.
 - Implement Command Post of the Future (CPoF) to exchange information and concepts on command and control and explore interoperable architecture demonstrating plug and operate capabilities.
 - Assess the operational utility of the CPoF Battleboard as the basis for defining future collaboration between Singapore and the U.S.
 - Conduct interoperability wargaming.
 - Conduct perception system prototype development testing in both laboratory and field.
 - Initiate development of novel quantum dot detector technology for new design concepts for micro-sensors.

- Sensor Dart
 - Develop initial design concept that addresses separate Sensor Dart versions for a Unit of Action deployment.
 - Conduct detailed trade studies and systems analysis that will be performed to maximize system capabilities.
 - Generate designs detailing the glider, dart, sensor, electronics, and communications subsystems.
 - Integrate Sensor Dart subsystems for flight testing.

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- Develop and flight test prototype glider and dart system.
- Demonstrate network sensor architecture for detecting heavy armor.

- WolfPack
 - Reduce form factor size of initial WolfPack capability hardware to suit multiple delivery options under the FCS architecture.
 - Expand initial WolfPack sensing capabilities to cover additional enemy military systems waveforms.
 - Optimize initial WolfPack power generation and management systems for longer endurance.

(U) Other Program Funding Summary Cost:

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------|---------|---------|---------|---------|
| PE 0603005A Army | 105.020 | 104.800 | 40.000 | 25.000 |

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Network-Centric Warfare Technology PE 0603766E, R-1 # 51 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 82.185 | 121.613 | 136.899 | 176.855 | 194.101 | 200.066 | 205.066 | 215.066 |
| Joint Warfare Systems NET-01 | 25.063 | 35.090 | 60.787 | 93.405 | 90.550 | 93.657 | 95.657 | 105.657 |
| Maritime Systems NET-02 | 9.076 | 34.327 | 33.426 | 38.532 | 48.774 | 51.839 | 53.839 | 56.839 |
| Classified NET-CLS | 48.046 | 52.196 | 42.686 | 44.918 | 54.777 | 54.570 | 55.570 | 52.570 |

(U) Mission Description:

(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 technology 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)*

| | <u>FY 2004</u> | <u>FY 2005</u> | <u>FY 2006</u> | <u>FY 2007</u> |
|----------------------------------|----------------|----------------|----------------|----------------|
| Previous President's Budget | 91.226 | 125.124 | 141.257 | 199.796 |
| Current Budget | 82.185 | 121.613 | 136.899 | 176.855 |
| Total Adjustments | -9.041 | -3.511 | -4.358 | -22.941 |
| | | | | |
| Congressional project reductions | 0.000 | -3.511 | | |
| Congressional increases | 0.000 | 0.000 | | |
| Reprogrammings | 0.000 | 0.000 | | |
| SBIR/STTR transfer | -9.041 | 0.000 | | |

(U) **Change Summary Explanation:**

FY 2004 Decrease reflects SBIR/STTR transfer.
 FY 2005 Decrease reflects congressional undistributed reductions.
 FY 2006 - 2007 Decrease reflects program adjustments in Project NET-CLS, classified programs.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Joint Warfare Systems NET-01 | 25.063 | 35.090 | 60.787 | 93.405 | 90.550 | 93.657 | 95.657 | 105.657 |

(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 leverages current and emerging network, robotic, and information technology and provides 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.

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(U) Program Accomplishments/Planned Programs :

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------|---------|---------|---------|---------|
| Network Command | 13.813 | 16.085 | 16.883 | 19.516 |

(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 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 is scheduled to transition to the Army Program Executive Office Command, Control, and Communications Tactical (PEO C3T) in April 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 will introduce 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 an outgrowth of the Command Post of the Future (CPOF) program that 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 allows users to be distinguished by their military function – intelligence, maneuver, fires, security, logistics – and tailors displays and communication modes to those functions. Finally, the technology scales the environment from dozens to hundreds of workstations operating over a diverse set of tactical communication networks.

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- 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 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.
- 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.

(U) Program Plans:

- Command Post of the Future.
 - Instrument the deployed CPOF software to record data from field use.
 - Develop analysis tools to reconstruct information paths.
 - Design system management tools to restructure information flows to meet decision needs.
- Multiuser, Adaptive Command Environment.
 - Collect data from field operations describing information flows, timing, and decision patterns.
 - Identify 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.

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- Network-Centric Situation Assessment.
 - Identify data fields available to a representative theater commander.
 - 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------------|---------|---------|---------|---------|
| Precision Urban Combat Systems (PUCS) | 0.000 | 4.000 | 10.423 | 22.565 |

(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, 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.

- The Robust, Persistent 3D Urban RSTA (reconnaissance, surveillance and target acquisition) program addresses the very difficult technical challenges to provide 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 Firefight Aerial Sensor and Mapper program will develop a new adaptive optical-acoustic sensor fusion system to identify the 3D dynamic locations of red and blue forces in continually updated 3D models of the urban landscape. The program will use a small number of UAVs (1-4) equipped with multi-modal sensor suites (IR, acoustic arrays) and rapidly updated 3D imagery. By detecting weapon discharge events, approximations of individual shooter locations are combined in order to obtain an informative overall picture of the emerging battlefield.
- 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 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 Head Mounted Alerting for Urban Operations program will provide unprecedented situation awareness capabilities to the warfighter without flooding the individual with excess information. The program will develop an intrusive alerting system that will allow a soldier to patrol and/or operate in an urban environment while being interrupted only by urgent and highly relevant situation awareness information. The program will employ an information management engine that filters, prioritizes, and presents diverse and copious amounts of situation awareness data, generically referred to as 'alerts', in accordance with a set of correlation rules created by each individual soldier. The filtering will be specialized to individual warfighter's roles and responsibilities and automated so the warfighter does not have to make real-time complicated adjustments to their tools when a dangerous situation erupts.
- 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.

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(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.

- Firefight Aerial Sensor and Mapper.
 - Develop prototype sensor system.
 - Collect weapon discharge and background signatures.
 - Develop battlefield activity summarization logic.
 - Demonstrate at a representative 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.
 - Demonstrate at a representative MOUT site.

- Head Mounted Alerting for Urban Operations.
 - Create information filters that sort situation relevant data from background.
 - Develop and prototype mechanisms to sense soldier's activity and situation intensity.
 - Demonstrate at a representative MOUT site.

- 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------|---------|---------|---------|---------|
| Effects Based Network Targeting | 4.253 | 5.877 | 2.062 | 0.000 |

(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.

(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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------------|---------|---------|---------|---------|
| Confirmatory Hunter Killer System | 6.997 | 9.128 | 9.741 | 12.481 |

(U) The Confirmatory Hunter-Killer System program is developing a low-cost, expendable loitering weapon/unmanned air vehicle for deployment along lines-of-communication or near critical facilities (e.g., suspect underground facilities). The objective is to provide localized surveillance against limited (one or two) specific targets. The vehicle employs two on-board electro-optics/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, emerging targets, and threats to lines of communication and other delimited regions. The program enables suppression of targets emerging from suspect underground facilities, thus providing the capability to suppress pop-up electronic warfare threats, before having an opportunity to emit. The Confirmatory Hunter Killer System is planned for transition to the Army, at the conclusion of Phase II anticipated to be completed by FY 2007.

(U) Program Plans:

- Characterize component capabilities (platform, sensor, and onboard automatic target recognition and data links).
- Develop and analyze alternative designs, using high-fidelity simulation and analysis tools in a variety of joint mission contexts.
- Select combinations of components that achieve the most effective system capabilities.
- Develop a brass-board platform, mountable on a standard test aircraft; verify sensor, automatic target recognition, 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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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | R-1 ITEM NOMENCLATURE Network-Centric Warfare Technology PE 0603766E, Project NET-01 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| SASO and Patrolling Enablers Yielding Enhanced Security (SPEYES) | 0.000 | 0.000 | 4.133 | 10.631 |

(U) The Stability and Support Operations (SASO) and Patrolling Enablers Yielding Enhanced Security (SPEYES) program develops and integrates a set of warfighter technologies into a comprehensive system tailored to enhance the effectiveness of U.S. forces in post-conflict military situations. These technologies act as force multipliers, allowing a small number of ground troops to exert influence comparable to larger forces without SPEYES. Core technologies include: 1) distributed, persistent multi-spectral cameras, 2) continuous, dynamic scheduling of patrols, and 3) tools for understanding rapidly evolving situations. When integrated, these technologies allow forces to provide security from three critical perspectives: 1) military policing (e.g., looters, thugs, black market activities), 2) force protection (including convoy security, command center, and base security), and 3) critical infrastructure protection (e.g., protection of oil pipelines, ports, borders). The SPEYES system is being tested against a range of scenarios and assessed for its ability to establish security and stability quickly which is critical for the eventual reconstruction effort.

(U) Program Plans:

- Establish a SPEYES testbed at a facility that supports company-level training in security operations.
- Develop prototypes of selected SPEYES technologies.
- Plan, conduct, and evaluate controlled experiments at the testbed to ascertain appropriate operational concepts of employment.
- Refine and ruggedize the design of selected prototypes.
- Conduct semi-annual evaluations of the refined designs in platoon-level exercises.
- Coordinate with Army and Marine program offices for transition to field use.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Multi Dimensional Mobility Robot (MDMR) | 0.000 | 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------|---------|---------|---------|---------|
| RADAR Flashlight | 0.000 | 0.000 | 4.500 | 6.000 |

(U) Current shortfalls exist in our capability for through-the-wall (TTW) detection or localization of adversaries or hostages in urban environments. Other programs are developing fixed multi-node / multistatic systems for synoptic surveillance of building interiors. The goal of this program is to develop a tactical portable handheld system that can be used to detect unique quasi-narrowband countermeasure-resistant signatures associated with enemy combatants and hostages through walls and doors using high gain processing. Range and angle resolution plus blind statistical signal separation techniques will be used to determine location and number of occupants.

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(U) The primary technical obstacles are a) miniaturization of sensor and signal processing, b) “virtual” platform stabilization using differential processing from stationary objects in field of view, and c) selection of optimum frequency for penetration, target discrimination and gain, and d) separation of multiple targets using both spatial and temporal processing using statistical signal separation techniques. This program is an outgrowth of “Building Structure and Activity Assessment” under PE 0603767E, Project SEN-01.

- (U) Program Plans:
- Evaluate candidate designs for RF and signal processing components.
 - Carry out feasibility measurements and modeling.
 - Design, build, and test prototypes for use in full-scale demonstration of the concept.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------|---------|---------|---------|---------|
| Network Centric Logistics | 0.000 | 0.000 | 5.045 | 11.972 |

(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 feedforward 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 stability, and (4) transport planning technology to enable unconventional commodity flows.

- (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.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
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- Exercise the decision protocols against a variety of combat scenarios.
- Conduct field evaluations of the technology in parallel with Service training exercises.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Network-Centric Warfare Technology PE 0603766E, Project NET-02 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Maritime Systems NET-02 | 9.076 | 34.327 | 33.426 | 38.532 | 48.774 | 51.839 | 53.839 | 56.839 |

(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 Reduced Size, Affordable Submarines technology demonstration program.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|---|---------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Mobile Undersea Distributed System (MUDS) Program | 9.076 | 25.927 | 19.426 | 20.032 |

(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 will investigate and demonstrate 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 will be demonstrated. This effort will develop 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. The military utility of underwater gliders will be demonstrated in a sensor system that is configurable in 3D, adaptable to the physical environment for sensing and communications, sustainable by getting its on-station locomotion and ‘staying power’ from the environment, self-configurable using sensory feedback, and self-optimizing using efficient dynamic network management techniques.

(U) The Persistent Ocean Surveillance effort 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, solar energy, temperature differentials, etc.) for their power, miniature geolocation technologies, and technologies for sensor data storage, transmission, and intra-field communications. The Persistent Ocean Surveillance-Station Keeping technology is planned for transition to the Navy is anticipated 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 (formerly Vortex Combustor in PE 0603763E, Project MRN-02) effort seeks to develop an energy-dense air independent underwater power source as a potential propulsion system for underwater vehicles. The Aluminum Combustor technology is anticipated for transition to the Navy in FY 2007.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Network-Centric Warfare Technology PE 0603766E, Project NET-02 | |

(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 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.

(U) The ability of U.S. Navy submarines to maintain situation awareness and tactical advantage in shallow water is compromised by an inability to safely deploy the highest-capability acoustic sensor, the long towed array. The Compact Aperture Ranging Passive Sonar (CARPS) effort will provide towed array capability in a compact hull or dome-mounted sonar aperture. CARPS will exploit non-acoustic shear waves induced in the material of a small aperture by external acoustic energy. The program will investigate 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**
 - Assess concepts employing swarms of undersea vehicles with acoustic and non-acoustic sensing modalities for detecting and tracking submarines with air-independent propulsion (AIP) systems.
 - Demonstrate autonomous control approaches for individual and groups of undersea vehicles.
 - Develop prototype low-cost, low-power, sensor/signal processing system, undersea sensor communications, and an underwater sensor localization and navigation capability.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Network-Centric Warfare Technology PE 0603766E, Project NET-02 | |

- Perform design trade studies, including: hydrodynamic performance modeling for advanced undersea vehicles concepts and advanced propulsion systems concepts.
- Assess concepts for precise sensor localization and navigation systems.
- Design and prototype a system of undersea autonomous with sensor modalities, communications, and navigation for detecting and localizing submarines equipped with AIP technology.
- Demonstrate system performance at sea.

- Persistent Ocean Surveillance
 - Explore the scientific/engineering issues associated with station keeping.
 - 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
 - Continue investigation into technologies for detection, precision identification, tracking and destruction of elusive surface, subsurface and air targets.
 - Refine and update impact assessment of introducing networked manned and unmanned systems, cognitive systems, and robust, secure self-forming tactical networks into the Navy's future warfighting capability concepts.

- 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.

- River Eye
 - Assess required sensor modalities, develop modeling techniques, and conduct field experiments in mixed estuary environments to establish proof of concept.

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- Conduct field experiments in stratified estuaries, incorporate environment data into model, and develop prototype mission planning application.
- 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)
 - Demonstrate the concept through analysis and simulation.
 - Construct a prototype aperture and verify its specifications in a tank test or sea test using a controlled source.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------|---------|---------|---------|---------|
| Jet Blast Deflector | 0.000 | 3.400 | 1.000 | 0.000 |

(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 has been signed 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|-----------------------------|---------|---------|---------|---------|
| Non-Linear Dynamics for ASW | 0.000 | 0.000 | 2.500 | 3.000 |

(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. This program will demonstrate that the nonlinear dynamics processing improves the minimum detectable signal level (MDL) performance of the Air Deployed Active Receiver (ADAR) system in a reverberation-limited environment. A nonlinear beamformer will be developed for the SSQ-101 ADAR sonobuoy based on arrays of coupled nonlinear oscillators implemented in analog VLSI demonstrating improved sidelobe performance. Significant technical challenges include array dynamic response, bandwidth response of the coherent source center frequency, synchronization to false targets, and increased main beam gain for weak signals.

(U) Program Plans:

- Develop system requirements for nonlinear ADAR beamformer.
- Develop analytical formulation of the nonlinear ADAR beamformer array dynamics.
- Develop high fidelity time series simulation for evaluating nonlinear beamformer performance.
- Develop quantitative assessment of potential improvement for realistic environments.
- Develop analog VLSI hardware of nonlinear oscillators.
- Develop prototype nonlinear beamformer and associated electronics compatible with ADAR sonobuoy.
- Demonstrate system performance in ADAR sonobuoy configuration using recorded data.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | R-1 ITEM NOMENCLATURE Network-Centric Warfare Technology PE 0603766E, Project NET-02 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------------|---------|---------|---------|---------|
| Reduced Size, Affordable Submarines | 0.000 | 5.000 | 10.500 | 15.500 |

(U) Based on the results of the DARPA/Navy Submarine Design Study and concepts explored under the MUDS concept from this PE/Project, the Tango Bravo technology demonstration program will explore design options for a reduced-size submarine with equivalent capability as 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. Additionally, reduced platform infrastructure provides the opportunity for greater payload volume. Although this effort is focused on projects that are driven by projected submarine requirements, it is recognized that several of these developments will have applicability to multiple Navy platforms that share similar inherent infrastructure (e.g., hydraulics, torpedo handling/launch, and sonar). This program will be 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 in September 2004, will jointly formulate technical objectives for critical technology demonstrations in: (1) propulsion concepts not constrained by a centerline shaft, (2) externally stowed and launched weapons (especially torpedoes), (3) conformal alternatives to the existing spherical sonar array, (4) technologies that eliminate or substantially simplify existing submarine hull, mechanical and electrical systems, and (5) automation to reduce crew workload for standard tasks. Several concepts will be explored with ultimately a 1/4 scale model being built and tested.

(U) Program Plans:

- Conduct a shaftless propulsion demonstration at an appropriate scale to validate key aspects of the concept such as system size and weight, propulsive efficiency, and acoustic and electromagnetic signatures, including predictive capability.
- Perform an integrated demonstration of the critical equipment required to provide external weapons launch at tactically useful speeds. Definition of the demonstration will include launch hydrodynamics and acoustics, as well as maintenance and health issues associated with prolonged weapon storage away from manned access.
- Conduct a demonstration to prove the critical technologies to show how a conformal alternative can provide the critical functionality of the spherical bow array on existing submarines.
- Develop and demonstrate concepts and technologies required to eliminate or substantially simplify existing shipboard systems (e.g., hydraulic/pneumatic vs. electrical actuation).

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- Develop and demonstrate automation approaches that provide equivalent or better performance with reduced manpower for activities that are currently personnel intensive (e.g., fire control party).

(U) Other Program Funding Summary Cost:

- Not Applicable.

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Sensor Technology PE 0603767E, R-1 # 52 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 0.000 | 201.917 | 189.452 | 200.088 | 221.894 | 220.919 | 222.919 | 221.919 |
| Surveillance and Countermeasures Technology SEN-01 | 0.000 | 67.236 | 58.957 | 70.058 | 83.388 | 85.456 | 85.956 | 85.956 |
| Sensors & Exploitation Systems SEN-02 | 0.000 | 134.681 | 130.495 | 130.030 | 138.506 | 135.463 | 136.963 | 135.963 |

(U) Mission Description:

(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. This program element and the projects funded within it were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0603762E, Projects SGT-02, SGT-03, and SGT-04.

(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 and strategic advantage, and the ability to deny and deceive enemy sensor systems.

(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; Building Structure and Activity Assessment; Surveillance and Threat Neutralization in Urban Environments; Counter Underground Facilities; Hostile Fire Indicator; RF MEMS Improvement; Low Cost Cruise Missile Defense; and Integrated Sensor Is Structure (ISIS).

(U) The Sensors and Exploitation Systems project develops and demonstrates advanced sensors, and exploitation technologies. These efforts 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-

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Sensor Technology PE 0603767E, R-1 # 52 | |

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.

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|------------|--|-----------------------|-----------------------|-----------------------|
| (U) | <u>Program Change Summary:</u> <i>(In Millions)</i> | <u>FY 2005</u> | <u>FY 2006</u> | <u>FY 2007</u> |
| | Previous President's Budget | 199.873 | 186.554 | 190.138 |
| | Current Budget | 201.917 | 189.452 | 200.088 |
| | Total Adjustments | 2.044 | 2.898 | 9.950 |

Please note that this program element has been newly created from portions of PE 0603762E. The *Previous President's Budget* amount reflects projects SGT-02, SGT-03 and SGT-04 previously funded in that PE.

| | |
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| Congressional program reductions | -4.856 |
| Congressional increases | 6.900 |
| Reprogrammings | 0.000 |
| SBIR/STTR transfer | 0.000 |

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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Applied Research | R-1 ITEM NOMENCLATURE Sensor Technology PE 0603767E, R-1 # 52 | |

(U) **Change Summary Explanation:**

FY 2005 Increase reflects a congressional adds for the Sandia Intelligent Systems and Robotics Center, 360 Degree Portable Surveillance and Reconnaissance Unit and Wireless Vibration Sensor Initiative offset by congressional reductions for the ISIS program and undistributed reductions.

FY 2006 - 2007 Increase reflects minor shifts in program pricing and phasing.

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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-01 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Surveillance and Countermeasures Technology SEN-01 | 0.000 | 67.236 | 58.957 | 70.058 | 83.388 | 85.456 | 85.956 | 85.956 |

(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. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0603762E, Projects SGT-02 and SGT-03 and is noted in a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|--------------------------------|----------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Counter-Underground Facilities | (15.300) | 18.000 | 14.000 | 14.000 |

(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. This program began by developing validated phenomenological models

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for a range of 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. One concept under development, the Deployable Unattended Ground Sensor System (DUGSS), 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. Another concept, 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. To support the demonstrations of these concepts, the CUGF program is also developing or modifying E-field, B-field, 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 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.
- 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|-------------------------------------|---------|---------|---------|---------|
| Digital Radio Frequency Tag (DRAFT) | (8.500) | 3.375 | 0.000 | 0.000 |

(U) The Digital Radio Frequency Tags program will develop a flexible, potentially low cost technology to allow radars (Moving Target Indicator (MTI) and Synthetic Aperture Radar (SAR)) to receive data from ground devices. This program will develop a small, lightweight and affordable RF Tag for data exfiltration from unattended ground sensors and 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 will be investigated and developed, adding additional communications capabilities to the tags for enhanced interoperability with combat identification and communications systems. These added capabilities will 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 will be 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 is planned for transition to the Army and to the Marines; anticipated completion by FY 2005.

(U) Program Plans:

- Complete 5 baseline radar tag prototype units.
- Complete design of advanced tag concepts.
- Conduct laboratory device testing and characterization.
- Conduct airborne field tests and user demonstration.
- Complete dual-mode tag communicator design.
- Demonstrate dual-mode tag communicating on SATCOM waveform.
- Develop dismount/red tag prototypes and conduct laboratory device testing and characterization.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------|---------|---------|---------|---------|
| Rescue Transponder | (2.200) | 6.000 | 2.000 | 0.000 |

(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 Activity at the conclusion of Phase 3 that is anticipated to be completed by FY 2006.

- (U) Program Plans:
- 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 partners.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Building Structure and Activity Assessment (Formerly Threat Character of Buildings) | (0.000) | 5.000 | 5.000 | 9.000 |

(U) This 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

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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.

(U) Program Plans:

- 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Surveillance and Threat Neutralization in Urban Environments | (0.000) | 4.000 | 4.000 | 6.000 |

(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; standoff identification and localization of explosive vapors/effluents; and multi-mode integrated acoustic - and radar-based systems to backtrack to the source of fire. 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.

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- (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.
 - Design, build, and test prototype for wide-area applications.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Nuclear Facilities and Materials Tracking Assessment (NUCTRAC) | (0.000) | 0.000 | 5.000 | 9.000 |

(U) The goal of the Nuclear Facilities and Materials Tracking and Assessment (NUCTRAC) program (continuation of advanced sensor processing studies initiated under PE 0602702E, Project TT-06, Advanced Tactical Technology) 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.
 - Develop sufficient system concept fidelity to validate program goals and objectives.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|----------|---------|---------|---------|
| Low-Cost Cruise Missile Defense (LCCMD) | (12.740) | 10.000 | 6.450 | 0.000 |

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 pursued six novel concepts and is presently focused on the maturation and demonstrations of radar seeker solutions employing active ESA concepts using low cost single-chip transmit/receive modules. The LCCMD technology is planned for transition to the Army's PEO-ASMD at the conclusion of Phase III, which is anticipated to be completed during 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.
- Integrate seeker with U.S. Army demonstration interceptor.
- Conduct end-to-end system performance via captive carry flight testing.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------------|---------|---------|---------|---------|
| Integrated Sensor Is Structure (ISIS) | (8.800) | 11.000 | 18.000 | 26.058 |

(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 100's 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+ months of autonomous, unmanned flight; 100's 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 and the Missile Defense Agency at the conclusion of Phase III that is anticipated to be completed by FY 2009.

(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).

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------|---------|---------|---------|---------|
| RF MEMS Improvement | (9.000) | 8.861 | 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:

- Develop process improvements, supported by predictive performance models, in competing MEMS fabrication and packaging techniques.
- Perform six design and testing iterations of packaged MEMS.
- Demonstrate ability to fabricate low-cost, low-loss, long life MEMS switches meeting DoD requirements.
- Demonstrate 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------|---------|---------|---------|---------|
| Hostile Fire Indicator (HFI) | (0.000) | 0.000 | 3.957 | 6.000 |

(U) The Hostile Fire Indicator (HFI) program is an airborne extension of the Boomerang Rapid Response program that will 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 will 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. This information can be relayed to the pilot, other friendly aircraft in the area, and mission planners and commanders for effective evasion, counter-fire, or follow-on engagement. The key technology element required for HFI is an advanced passive electrostatic sensor system derived from the same technology developed for stand-off electrocardiograms. The sensors are extremely small, lightweight, and low cost.

(U) The principle technical challenge in the HFI program is the effective integration and demonstration of the sensor net and processing system into an operating aircraft under realistic operating conditions. This program will be executed in conjunction with United States Special Operations Command (USSOCOM) and U.S. Army rotorcraft aviation organizations, including U.S. Army Special Operations Command (USASOC) -directed live-fire evaluations with an HFI-enabled aircraft as the final objective evaluation and demonstration. The HFI technology is planned for transition to USSOCOM and USA SOC at the conclusion of Phase 2 that is anticipated to be completed by FY 2007.

(U) Program Plans:

- Measure background noise on two U.S. Army and four SOF helicopters.
- Demonstrate 1000m downrange projectile detections.
- Optimize signal processing for the operational on aircraft electromagnetic noise environment.
- Demonstrate 10m cross-range bullet detection capability.
- Demonstrate projectile source location capability.
- Demonstrate full HFI capability on unmanned a full-scale model under live fire conditions.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------|---------|---------|---------|---------|
| Affordable Large Array (ALA) | (2.100) | 0.000 | 0.000 | 0.000 |

(U) The Affordable Large Array (ALA) program has developed ultra-low cost, lightweight, and low-power density X-Band transceivers and related technologies for potential use in conjunction with very large but foldable and easily transportable antenna apertures. The technical challenges addressed under this program include the development of single chip transmit/receive modules with very low overhead power, (efficient and lightweight), techniques for distributing wideband RF, control signals, and DC power throughout the large arrays, and methods for dynamically calibrating these large flexible arrays. Other potential applications of ALA technologies include easily transportable, less expensive Ground Based Radar systems and aerostat-based systems for observing very low flying targets.

(U) **Program Plans:**

- Conducted studies and experiments to develop alternative array feed technologies that are applicable to very large arrays.
- Conducted power-aperture trade studies to determine the appropriateness of these technologies for applications including ground-based radars, radars for mid-course cruise missile defense and airborne low-power-density, large-scale radars.
- Completed testing of prototype transmit/receive (T/R) cells fabricated in SiGe, InP, and GaAs.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------------|---------|---------|---------|---------|
| Wireless Vibration Sensor Initiative | 0.000 | 1.000 | 0.000 | 0.000 |

(U) Continues support of the development and qualification of open system architecture wireless sensor technology.

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

- Not Applicable.

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| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Sensors and Exploitation Systems SEN-02 | 0.000 | 134.681 | 130.495 | 130.030 | 138.506 | 135.463 | 136.963 | 135.963 |

(U) Mission Description:

(U) The Sensors and Exploitation Systems project develops and demonstrates advanced sensors, 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. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0603762E, Project SGT-04 and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|--|----------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| Advanced Exploitation Systems Technology | (47.007) | 42.098 | 39.182 | 38.463 |

(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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- Frequency-Diverse Spatial/Spectral Sensor Exploitation 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.
- The National/Tactical Exploitation (NTEX) initiative develops technologies to locate and identify enemy air defense 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 managed by the “Geospatial Intelligence Advancement Testbed” project at NGA. 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 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. DARPA established an MOA with the Night Vision and Electronic Sensors Directorate for this program in August 2004. The NTEX technology is planned for transition to an operational partner at the conclusion of Phase III anticipated to be completed by FY 2006.
- Video Verification and Identification (VIVID) develops technology to automate moving target strike operations for unmanned aerial vehicles (UAVs). 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 investigates 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 track multiple vehicular targets through dense traffic in military areas of operation overseas and supports target area searches for non-combatants and “no-strike” entities, to mitigate collateral damage. 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 is

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establishing an MOA with the Air Force and Navy for this program. The VIVID technology is planned for transition at the conclusion of Phase II which is anticipated to be completed by FY 2007.

- Tactical Sensor Network Technologies (TSNT) 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.
- 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 LADAR and IFSAR. The data represent a rich resource for use in precision target identification. E3D demonstrates that the target identification value of 3-D information greatly surpasses that of 2-D image-based methods. Program effort consists of three modules: (1) The Target Recognition module investigates the object recognition process; (2) The Target Acquisition module develops methods based on search of a local 3-D volume for possible targets; and (3) The Modeling module enhances identification methods based on detailed shape analysis. The resulting software tools are designed to be integrated into numerous ground stations to receive 3-D sensor data. The E3D technology is planned for transition to the Army and the Joint Precision Strike Demonstration at the conclusion of Phase IV anticipated to be completed in FY 2005.
- 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 interest; and (4) processes and manages the voluminous data produced by various sensors in time to provide the warfighter information required to prosecute TSTs.

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- 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 discriminants. 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.
- The Automatic Target Recognition Technology thrust develops new approaches to characterize targets in high volume sensor data with minimal human participation and supports very large sets of targets (thousands of target types) with high identification performance and very low false alarm rates. The program develops modeling methods to account for target variability, caused by partial damage, design difference, or equipment loaded onto the exterior of the vehicle and will support interaction with humans to supply operational context, guide hypothesis development, and adapt models. While developing techniques for in-the-field training of models, signatures, and scoring parameters, it will identify vehicle-specific signatures and develop new target fingerprinting techniques. Finally, new methods to assist humans in achieving precise identification of ad hoc poorly defined targets will be developed. The program supports rapid and accurate detection, recognition, and identification of targets in high volume sensor imagery and enables a dramatic reduction in sensor-to-shooter timelines, supporting dynamic target engagement.

(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.
 - 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.

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- National/Tactical Exploitation.
 - Demonstrate the ability to recognize components of specific air defense 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 of Identity.
 - Develop techniques to automate detection, classification, and tracking of enemy, mobile, surface targets in visible and infrared motion imagery acquired by unmanned air vehicles.
 - Develop automated techniques to detect moving vehicles and unintended casualties in the vicinity of an impending weapon strike.
 - 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.
 - 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.
 - Provide additional synthetic data and collect advanced laser radar (LADAR) data for research and development modules.
 - 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.

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- 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.
 - 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 use 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.
 - Evaluate performance by comparing reconstructions with the shape, surface material, equipment, and mobility characteristics measured on the actual vehicles.
- Automatic Target Recognition Technology.
 - Obtain a constant supply of data from field and developmental sensors, covering multiple target types in numerous environmental settings.
 - Obtain or estimate ground truth for those data to provide a foundation for periodic performance assessments.
 - Extend existing performance analyses to provide bounds on detection, identification, and fingerprinting performance for thousands of vehicle types.

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- Develop model generation, model update, detection, recognition, identification, and fingerprinting algorithms based on a range of technical approaches.
- Periodically assess technologies on the field data, computing statistically significant estimates of performance to compare against the performance analyses.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|----------|---------|---------|---------|
| Network Centric Sensing and Engagement | (29.891) | 28.144 | 39.683 | 43.843 |

(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:

- 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)

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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. The program separately developed a novel Ku band directional antenna. The antenna promises 20+Mbit/s connectivity between intelligence, surveillance and reconnaissance assets, tactical aircraft, and small unmanned air vehicles using the Common Data Link family of radios. The TTNT technology is planned for transition to the Air Force, Army, Marine Corp, and Navy at the conclusion of Phase III, that is anticipated to be completed by FY 2006.

- The Rotorcraft SIGINT/COMINT Geolocation initiative develops network-based signal geolocation technology for rotorcraft application. The program enables collaborative interaction between multiple rotorcrafts (manned or unmanned) for mapping, location and engagement of RF emitters. This effort develops techniques to mitigate rotor blade induced multipath. It demonstrates appropriate receiver, signal processing and antenna technology, enabling ad hoc rotorcraft networks to rapidly characterize emitters.
- 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 colocated with operational analysts, and transition takes place incrementally as individual technologies mature.
- 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

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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.

(U) Program Plans:

- Camouflaged Long Endurance Nano-Sensors.
 - 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.
 - Complete brassboard design and fabrication.
 - Complete brassboard TTNT flight experiments and demonstrations at large scale.

- Rotorcraft SIGINT/COMINT Geolocation.
 - Analyze interactions between threat signals and rotor blades.
 - Validate analyses with tower tests.
 - Build a prototype airborne system.
 - Validate single-ship performance with flight tests.
 - Interface prototypes to the inter-ship communications net.
 - Demonstrate multi-ship operation in flight tests.

- Federated Object-level Exploitation.
 - Acquire real-time access to data from all-source national and tactical sensors operating over an area of interest.
 - Establish connectivity among a minimum of three testbed sites at which those data can be received.

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- Build a baseline evaluation testbed by assembling best-of-breed technologies for site modeling, target recognition, and target tracking.
- Create a design for a federated set of algorithms that allow multiple sites to construct various parts of a situation estimate.
- Implement and test protocols for ensuring statistical consistency between estimates maintained at different sites.
- Obtain data that can serve as ground truth for evaluating algorithm performance.

- Persistent Operational Surface Surveillance and Engagement
 - 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.
 - 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.
 - Deliver initial POSSE exploitation system to Iraqi theatre and provide technical support as required.
 - Implement planned enhancements and additions, and deliver to theatre in accordance with POSSE spiral development plan.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|------------------------------------|----------|---------|---------|---------|
| Advanced Optical Sensor Technology | (21.464) | 26.519 | 26.869 | 26.962 |

(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:

- Standoff Precision ID in 3-D (SPI 3-D) develops an affordable sensor package capable of high-resolution 3-D images for confirmatory ID at long ranges. The sensor overcomes weapons-effects obscuration and penetrates foliage, camouflage, and cloud layers. The system provides intensity, range and polarization for each pixel in the field of view. The program conducts a series of ground, air and unmanned

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air vehicle demonstrations of standoff 3-D LADAR precision ID 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-moving targets. Demonstrations employ existing commercial-off-the-shelf optics, focal plane arrays and gimbals, combined with a novel polarization-to-range mapping technique. The SPI-3D technology is planned for transition to the Air Force at the conclusion of Phase III that is anticipated to be completed by FY 2008.

- The Synthetic Aperture Ladar for Tactical Imaging (SALTI) initiative will develop and demonstrate an airborne interferometric synthetic advanced laser radar (Ladar) imager capable of producing high-resolution three-dimensional imagery at long ranges. The ultimate SALTI system will combine 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 and fit within a tactical-sized package suitable for deployment on a long-range unmanned air vehicle such as the Global Hawk. 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. The SALTI technology is planned for transition to the Air Force by FY 2007.
- The Video Exploitation for Precision Identification initiative leverages numerous video sensors being introduced into the battlespace, providing more persistent and ubiquitous sensing over larger areas of interest. This initiative explores new ways to enhance the performance of target recognition and site monitoring techniques through use denser data sets that exhibit high temporal and spatial sampling rates, long-term observation, and perspective diversity. Particular topics of interest include: (1) video data mining (e.g., extracting and representing behavior, representing and recognizing events and patterns of events, and characterizing patterns of object motion); (2) learning for recognition and monitoring, (e.g., learning object categories from stereo or video sequences and learning event and behavior normalcy models); (3) modeling-on-the-fly (e.g., creation of active models and models that use recent advances in camera modeling and extraction of geometric information and invariants); (4) novel sensing techniques (e.g., dense, inexpensive camera arrays, polarization-sensing video cameras, and novel image formation processes that could extract new or different types of information, such as imaging through foliage or walls); (5) innovative space-time visualization concepts (e.g., new approaches to 4D visualization or visualization using video flashlights or paintbrushes); and (6) new approaches to recognition (e.g., recognizing classes of objects, inferring and reasoning about function, using scene or site models to object identification or characterization, recognizing events, and using multi-view geometry, 3D curves, affine patches, or other invariant or semi-invariant techniques).

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- The High Precision Long Range Laser Designator/Locator (HPLD) initiative 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 over 5 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. DARPA established an MOA with the Night Vision and Electronic Sensors Directorate for this program in August 2004. The High Precision Long Range Designator/Locator technology is planned for transition to the Army and SOCOM by FY 2008.
- 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.

(U) Program Plans:

- Standoff Precision ID in 3-D.
 - Develop and test brassboard of complete imaging system, including laser and Pockels cell elements.
 - Determine accuracy and precision of ranging technique.
 - Develop flight engineered system.
 - Perform full-up ground tests from mountaintop test range.
 - Integrate and demonstrate system from manned aircraft against moving targets.
 - Integrate system into air vehicle and fully demonstrate against a variety of ground targets.
- Synthetic Aperture Ladar for Tactical Imaging.
 - Develop a laser transmitter containing an extremely stable local optical oscillator and other oscillators, modulators and power amplifiers necessary to create the time-dependent waveform and power required for synthetic aperture imaging.
 - Develop a multi-element detector array including analog and digital electronics for coherently reading all elements of the array.
 - Integrate the detector array with an optical master oscillator to form a coherent receiver.

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- Develop image formation processing algorithms to coherently combine multiple laser pulse returns and to compensate for platform motion during the collection of these multiple pulses.
- Demonstrate the collection of optical synthetic aperture imagery from an airborne platform and that produces high-resolution 2D and 3D image products.
- Characterize coherent infrared propagation through the atmosphere under operational conditions, to assess the feasibility of long range operation.

- 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.

- 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 in excess of 5 kilometers.
 - 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
 - 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.

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| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|----------------------------------|----------|---------|---------|---------|
| Advanced Radar Sensor Technology | (26.214) | 32.020 | 24.761 | 20.762 |

(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:

- The Wide Area All Terrain Change Indication and Tomography (WATCH-IT) initiative is developing 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 develops 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 is planned for transition to the NGA at the conclusion of Phase II, anticipated to be completed by FY 2005.
- The Knowledge Aided Sensor Signal Processing and Expert Reasoning (KASSPER) initiative radically alters the fundamental “front-end” signal processing architectures of advanced military sensors. It accomplishes 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

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estimate the background interference using sample statistical estimation. This necessarily entails an explicit assumption of stationarity. However, sensors operating in real environments around the world demonstrate that this homogeneity assumption is not valid. The problem manifests itself in increased false alarms, decreased target detections, and substantially degraded minimal detectable velocities in GMTI systems. KASSPER leverages the advent of detailed databases and high fidelity models to address inhomogeneities and non-stationarity at the front end of adaptive signal processing systems. Key technologies include advanced algorithms and high-performance computing architectures capable of memory-intensive adaptive signal processing. The program includes data collections, and a real-time demonstration of its processing gains. The KASSPER technology is planned for transition to the Air Force during FY 2005.

- The Generation After Next Airborne Surveillance Radar (GAN) initiative will evaluate new concepts for wide area coverage airborne ground surveillance radar technology by exploiting wide-beam staring systems rather than narrow-beam scanning systems. This approach would overcome challenges associated with low revisit rates, limited concurrency of modes, low power efficiency, low resolution, and sensor management. It is hypothesized that by supporting several modes on the aperture concurrently, GAN could offer better than an order-of-magnitude improvement in radar productivity relative to current and emerging systems.
- The Tethered Ultra-Long baseline Sparse Aperture (TULSA) initiative is developing new means of exploiting single-ship airborne long-baseline sparse apertures. This initiative develops techniques for deploying, calibrating, powering, feeding and processing received signals from active end bodies deployed on long, towed tethers. TULSA also develops 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. TULSA promises high-confidence geolocation of emitters from a single aircraft and provides commanders with characterization and targeting information for facilities, vehicles, and dismounted targets. The program also delivers tactical situation awareness and supports strategic indication and warning.
- 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.

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(U) Program Plans:

- Wide Area All Terrain Change Indication and Tomography.
 - Collect data using low-frequency, high-resolution polarimetric SARs.
 - Quantify the robustness of wide area change detection to factors, such as aircraft heading, depression angle, database aging, topography and terrain cover. Exploit initial target and clutter data collected at Camp McCain, MS and Fort Huachuca, AZ.
 - Assess 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.
 - Quantify the probability of detection and false alarm rate for a range of operating conditions.
 - Investigate methods to generate synthetic target signatures using software models or scaled frequency measurements.
 - Demonstrate WATCH-IT using the Foliage Penetration (FOPEN) SAR Advance Technology Development (ATD) system. Demonstrate real-time, on-board change detection and high-speed discrimination processing in the ground station.
 - Develop a system specification for a fully integrated WATCH-IT system.
 - Develop, integrate, install, and flight test the WATCH-IT on a manned or unmanned aircraft.

- Knowledge Aided Sensor Signal Processing and Expert Reasoning.
 - 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.
 - Demonstrate KASSPER performance gains in real-time processing environment using real data sets.

- Generation After Next Airborne Surveillance Radar.
 - Develop missions and concepts of operation to evaluate GAN sensor concepts.
 - Outline basic functional requirements to support proposed missions and concepts of operation.
 - Develop strawman concepts for GAN and evaluate their ability to satisfy the specified functional requirements.
 - Establish basic technology requirements.
 - Develop a roadmap outlining an objective GAN system and an investment strategy.
 - Develop a GAN prototype system and demonstrate its effectiveness in field activities.

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- Tethered Ultra-Long baseline Sparse Aperture.
 - Develop and demonstrate a multi-sensor localization concept.
 - Develop and evaluate relative navigation concepts to achieve desired geolocation accuracy.
 - Develop system and demonstrate the system capability against significant targets.

- Networked Detection and Ranging.
 - 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| 360 Degree Portable Surveillance and ReConn Unit | (0.000) | 2.400 | 0.000 | 0.000 |

(U) The 360 Degree Portable Surveillance and ReConn Unit project will design and fabricate an extremely large format video camera suitable for airborne reconnaissance by military forces in Iraq and elsewhere. The goal is 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. These capabilities have enormous potential to tip the scale in the battle against emplaced, and vehicle-borne improvised explosive devices (IEDs) and other asymmetric warfare scenarios.

- (U) Program Plans:
- Create 48 M-pixel MegaSkyCam from modular components (digital focal panes, GPS and data links).
 - Integrate eight MegaSkyCams to create the end device.
 - Demonstrate detection and tracking algorithms on an array of processors to produce automated alerts.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | R-1 ITEM NOMENCLATURE Sensor Technology PE 0603767E, Project SEN-02 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Sandia Intelligent Systems & Robotics Center | (0.000) | 3.500 | 0.000 | 0.000 |

(U) Fund selected research projects at the Sandia Intelligent Systems & Robotics Center.

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

- Not Applicable.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
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| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | | | | R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, R-1 # 53 | | | | |
| COST (In Millions) | FY 2004 | F Y2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 0.000 | 114.330 | 103.272 | 111.473 | 129.095 | 124.853 | 115.853 | 115.853 |
| Guidance Technology GT-01 | 0.000 | 41.452 | 52.420 | 57.824 | 64.150 | 59.000 | 50.000 | 50.000 |
| Classified GT-CLS | 0.000 | 72.878 | 50.852 | 53.649 | 64.945 | 65.853 | 65.853 | 65.853 |

(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. This program element was created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0603762E, Projects SGT-01 and SGT-CLS.

(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 program.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, R-1 # 53 | |

| | | | | |
|------------|--|-----------------------|-----------------------|-----------------------|
| (U) | <u>Program Change Summary:</u> <i>(In Millions)</i> | <u>FY 2005</u> | <u>FY 2006</u> | <u>FY 2007</u> |
| | Previous President's Budget | 137.244 | 138.271 | 149.610 |
| | Current Budget | 114.330 | 103.272 | 111.473 |
| | Total Adjustments | -22.914 | -34.999 | -38.137 |

Please note that this program element has been newly created from projects previously funded in PE 0603762E. The *Previous President's Budget* amount reflects projects SGT-01 and SGT-CLS funded under that PE.

| | |
|----------------------------------|---------|
| Congressional program reductions | -22.914 |
| Congressional increases | 0.000 |
| Reprogrammings | 0.000 |
| SBIR/STTR transfer | 0.000 |

(U) **Change Summary Explanation:**

FY 2005 Decrease reflects congressional undistributed reductions.
 FY 2006 - 2007 Decrease reflects program adjustments in the classified project.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| 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 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Guidance Technology GT-01 | 0.000 | 41.452 | 52.420 | 57.824 | 64.150 | 59.000 | 50.000 | 50.000 |

(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 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. This program element and project were created in accordance with congressional intent in the FY 2005 DoD appropriations bill. Prior year funding was budgeted in PE 0603762E, Project SGT-01 and is noted as a memo entry in each program below.

(U) Program Accomplishments/Planned Programs:

| | | | | |
|--------|----------|---------|---------|---------|
| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
| MEDUSA | (25.500) | 23.452 | 18.000 | 12.824 |

(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

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, Project GT-01 | |

(3) develop and demonstrate an end-to-end MEDUSA system. The MEDUSA technology is planned for transition to the Air Force at the conclusion of Phase III, which is anticipated to be completed during FY 2007.

(U) Program Plans:

- Developed and evaluated MEDUSA countermeasure and classification techniques and conduct phenomenological measurements.
- Fabricated and evaluated critical component technologies.
- Developed MEDUSA system designs.
- Build and demonstrate, from a tower, the breadboard MEDUSA design against realistic targets and environments.
- Build and field/flights test a MEDUSA brassboard design against realistic targets and environments.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------|---------|---------|---------|---------|
| Advanced Gyroscopes | (4.836) | 4.500 | 5.420 | 5.500 |

(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 gravity – gradiometer – based technologies.

(U) Program Plans:

- Develop concepts for achieving the required accuracy. Evaluate feasibility of underlying approach via analysis and laboratory measurements.
- Evaluate feasibility of underlying approach via analysis and laboratory measurements.
- Design, build, and test prototype navigation system.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, Project GT-01 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------------|---------|---------|---------|---------|
| Precision Inertial Navigation Systems | (3.500) | 8.500 | 15.500 | 14.500 |

(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 2007.

(U) Program Plans:

- Develop and demonstrate an inertial navigation system with positional bias drift rate below 5 meters/hour.
- Develop integrated “atom-chips” using Bose-Einstein condensate-based coherent atom sources, including integrated waveguides, vacuum systems, and atom detectors.
- Develop compact narrow-linewidth, tunable 780 nm laser sources with large modulation bandwidth via monolithic solid-state microchip design.
- Explore novel atom interferometer component designs, including BEC waveguides, guided atom beamsplitters.
- Demonstrate motion-compensated gravity gradiometer.
- Demonstrate approaches for GPS free navigation combining MEMS inertial navigation with locally derived location position information.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, Project GT-01 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---------------------------------------|---------|---------|---------|---------|
| Navigation Via Signals of Opportunity | (0.000) | 5.000 | 10.500 | 13.000 |

(U) The Navigation via Signals of Opportunity (NAVSOPP) program 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 NAVSOPP program will use signals of opportunity and specialized signals from a variety of ground-, air-, and space-based sources; these will be received on the warfighters' forth coming software defined radios, and will use specially tailored algorithms to determine position. 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. The NAVSOPP 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 NAVSOPP 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 NAVSOPP 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.

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---------|---------|---------|---------|
| Navigation-Grade MEMS Inertial Measurement Unit (IMU) | (0.000) | 0.000 | 3.000 | 12.000 |

(U) The Navigation-Grade MEMS Inertial Measurement (IMU) program will develop tiny 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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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| 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 2004 | FY 2005 | FY 2006 | FY 2007 |
|--------------------------------------|---------|---------|---------|---------|
| Global Positioning Experiments (GPX) | (2.000) | 0.000 | 0.000 | 0.000 |

(U) The Global Positioning Experiments (GPX) program increased the ability of GPS users to operate effectively in the presence of enemy jamming or countermeasures by demonstrating the feasibility of airborne pseudolite (APL) concepts. By receiving and re-transmitting GPS signals at substantially higher power levels, the APL overcomes the effects of jamming on DoD receivers and enable continuous operation. APLs can be rapidly deployed on unmanned aerial vehicles (or other airborne platforms) and provide theater-wide coverage for individual soldiers, combat platforms and precision GPS-guided shoot-to-coordinate weapons. The GPX program culminated with an integrated demonstrations of a full constellation of APLs which utilized shaped transmit beams in a jamming field and successfully showed it's utility for the JDAM weapon system with captive carry flights on an F/A-18 In addition, APL methods have been investigated for exploitation of signals from satellites of opportunity for precision localization in the absence of GPS. GPX program is transitioning to the Air Force GPS program office, which is currently conducting an implementation analysis.

- (U) Program Plans:
- Fabricated and integrated multiple airborne pseudolites.
 - Conducted airborne testing campaign; demonstrated successful navigation and interoperability in GPS jamming environment using multiple airborne pseudolites.
 - Demonstrated shaped transmit beam solution to near-far issue.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development | R-1 ITEM NOMENCLATURE Guidance Technology PE 0603768E, Project GT-01 | |

| | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|--|---------|---------|---------|---------|
| Advanced Tactical Targeting Technology (AT3) | (3.000) | 0.000 | 0.000 | 0.000 |

(U) The Advanced Tactical Targeting Technology (AT3) program demonstrated a passive tactical targeting system against short-dwell emitters to improve lethal suppression of enemy air defenses (SEAD). The targeting system is designed to negate emitter shutdown tactics now employed to defeat anti-radiation missiles (ARM) guidance, and thereby enable simplified ordnance inventories. The goal was to generate and distribute near real-time, comprehensive, and highly precise location of threat radars to all theater combatant aircraft without deploying any additional SEAD-dedicated, emitter-collecting platforms. AT3 accomplished this by widely deploying emitter collection packages hosted on existing airborne platforms, including combat aircraft. AT3 integrated distributed multi-platform emitter collections in real-time using existing or planned tactical data links with advanced network management and signal processing. To achieve wide deployment, AT3 focused on transition through inexpensive-upgrades to digital radar warning receivers. Enabling technologies include: coupled GPS Inertial Measurement Unit (IMU) packages, tactical communications, advanced highly dynamic data fusion network management capabilities, and algorithms to ensure robust, flexible performance of geolocation algorithms for locating multiple emitter types in noisy, high pulse density environments. AT3 has successfully completed strenuous flight tests and real-time multi-ship demonstrations with brassboard hardware. The AT3 technology is transitioning to the Air Force and Navy in FY 2005.

- (U) Program Plans:
- Completed and analyzed results from real-time flight tests at western test ranges to ensure that program goals were met.
 - Demonstrated AT3 technologies and capabilities.
 - Supported transition to Air Force and Navy.

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

- Not Applicable.

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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | DATE February 2005 | |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA6 Management Support | | | | R-1 ITEM NOMENCLATURE Management Headquarters (Research and Development) PE 0605898E, R-1 # 143 | | | | |
| COST (In Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 | FY 2008 | FY 2009 | FY 2010 | FY 2011 |
| Total Program Element (PE) Cost | 45.925 | 46.264 | 49.472 | 48.778 | 50.119 | 51.172 | 52.244 | 53.299 |
| Management Headquarters (R&D) MH-01 | 45.925 | 46.264 | 49.472 | 48.778 | 50.119 | 51.172 | 52.244 | 53.299 |

(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 2004 | FY 2005 | FY 2006 | FY 2007 |
| Management Headquarters | 45.925 | 46.264 | 49.472 | 48.778 |

(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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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | DATE February 2005 |
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA6 Management Support | R-1 ITEM NOMENCLATURE Management Headquarters (Research and Development) PE 0605898E, R-1 # 143 | |

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

| | <u>FY 2004</u> | <u>FY 2005</u> | <u>FY2006</u> | <u>FY 2007</u> |
|----------------------------------|----------------|----------------|---------------|----------------|
| Previous President's Budget | 44.525 | 46.689 | 47.800 | 47.800 |
| Current Budget | 45.925 | 46.264 | 49.472 | 48.778 |
| Total Adjustments | 1.400 | -0.425 | 1.672 | 0.978 |
| | | | | |
| Congressional program reductions | 0.000 | -0.425 | | |
| Congressional increases | 0.000 | 0.000 | | |
| Reprogrammings | 1.400 | 0.000 | | |
| SBIR/STTR transfer | 0.000 | 0.000 | | |

- (U) **Change Summary Explanation:**
- FY 2004 Increase reflects a below threshold reprogramming for the pay raise increase to 4.1 percent.
 - FY 2005 Decrease reflects congressional undistributed reductions.
 - FY 2006 - 2007 Increase reflects costs budgeted for the audit of financial statements and financial feeder systems.

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

- Not Applicable.