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**Department of Defense Fiscal Year (FY) 2005 Budget Estimates  
February 2004**



**RESEARCH, DEVELOPMENT, TEST AND EVALUATION, DEFENSE-WIDE  
Volume 1 - Defense Advanced Research Projects Agency**

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**DEPARTMENT OF DEFENSE  
BUDGET ESTIMATES FY 2005**

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# DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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Defense Adv Research Projects Agcy  
FY 2005 RDT&E PROGRAM

EXHIBIT R-1

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

Date: FEB 2004

| Line<br>No | Program<br>Element<br>Number | Item   | Act | Thousands of Dollars |                  |                  | S<br>E<br>C |
|------------|------------------------------|--|-----|----------------------|------------------|------------------|-------------|
|            |                              |  |     | FY 2003              | FY 2004          | FY 2005          |             |
| 2          | 0601101E                     | Defense Research Sciences                          | 1   | 171,383              | 139,434          | 143,729          | U           |
|            |                              | <b>Basic Research</b>                              |     | <b>171,383</b>       | <b>139,434</b>   | <b>143,729</b>   |             |
| 12         | 0602301E                     | Computing Systems and<br>Communications Technology | 2   | 390,607              | 334,696          | 342,614          | U           |
| 13         | 0602302E                     | Embedded Software and Pervasive<br>Computing       | 2   | 54,870               | 13,250           |                  | U           |
| 14         | 0602383E                     | Biological Warfare Defense                         | 2   | 157,861              | 149,105          | 147,533          | U           |
| 16         | 0602702E                     | Tactical Technology                                | 2   | 168,826              | 247,405          | 339,175          | U           |
| 17         | 0602712E                     | Materials and Electronics<br>Technology            | 2   | 414,437              | 465,450          | 502,044          | U           |
|            |                              | <b>Applied Research</b>                            |     | <b>1,186,601</b>     | <b>1,209,906</b> | <b>1,331,366</b> |             |
| 32         | 0603285E                     | Advanced Aerospace Systems                         | 3   | 242,095              | 315,941          | 361,067          | U           |
| 40         | 0603739E                     | Advanced Electronics Technologies                  | 3   | 158,847              | 186,748          | 218,151          | U           |
| 43         | 0603760E                     | Command, Control and<br>Communications Systems     | 3   | 115,654              | 193,562          | 225,784          | U           |
| 44         | 0603762E                     | Sensor and Guidance Technology                     | 3   | 216,052              | 336,658          | 337,117          | U           |
| 45         | 0603763E                     | Marine Technology                                  | 3   | 26,164               | 13,751           |                  | U           |
| 46         | 0603764E                     | Land Warfare Technology                            | 3   | 164,634              | 81,513           | 63,121           | U           |
| 47         | 0603765E                     | Classified DARPA Programs                          | 3   | 261,851              | 218,192          | 238,131          | U           |
| 48         | 0603766E                     | Network-Centric Warfare Technology                 | 3   |                      | 91,226           | 125,124          | U           |
|            |                              | <b>Advanced Technology Development (ATD)</b>       |     | <b>1,185,297</b>     | <b>1,437,591</b> | <b>1,568,495</b> |             |
| 124        | 0605502E                     | Small Business Innovative Research                 | 6   | 64,848               |                  |                  | U           |
| 132        | 0605898E                     | Management HQ - R&D                                | 6   | 44,850               | 44,525           | 46,689           | U           |
|            |                              | <b>RDT&amp;E Management Support</b>                |     | <b>109,698</b>       | <b>44,525</b>    | <b>46,689</b>    |             |



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Defense Adv Research Projects Agcy  
 FY 2005 RDT&E PROGRAM

EXHIBIT R-1

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

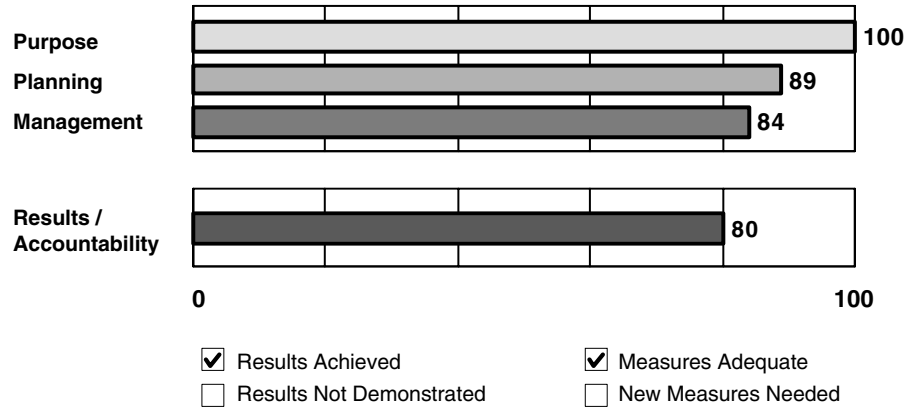
Date: FEB 2004

| Line<br>No | Program<br>Element<br>Number | Item   | Act | Thousands of Dollars |           |           | S<br>E<br>C |
|------------|------------------------------|--|-----|----------------------|-----------|-----------|-------------|
|            |                              |  |     | FY 2003              | FY 2004   | FY 2005   |             |
| 139        | 0909999E                     | Financing for Cancelled Account<br>Adjustments | 6   | 2,000                |           |           | U           |
|            |                              | RDT&E Management Support                       |     | 2,000                |           |           |             |
|            |                              | Total Defense Adv Research Projects Agcy       |     | 2,654,979            | 2,831,456 | 3,090,279 |             |

**Program: Basic Research**

**Agency:** Department of Defense--Military

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



**Key Performance Measures**

**Year Target Actual**

| Key Performance Measure   | Year           | Target | Actual |
|---|----------------|--------|--------|
| 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 and later | 100%   |        |
|   |                |        |        |
|   |                |        |        |
| Long-term Measure:<br>Portion of funded research that is chosen on the basis of merit review<br>Reduce non-merit-reviewed and -determined projects by one half in two years (from 6.0% to 3.0%)                                   | 2005           | -50%   |        |
|   |                |        |        |
|   |                |        |        |
|   |                |        |        |
|   |                |        |        |
|   |                |        |        |

**\*Rating: Effective**

**Program Type** Research and Development

**Program Summary:**

The Basic Research program includes scientific study and experimentation to increase fundamental knowledge in the physical, engineering, environmental and life sciences and consists of a wide portfolio of projects. The program is carried out primarily through grants to universities and non-profits. The results of this research are expected to improve the country's defense capabilities, although the actual results of any specific project are unpredictable. Notable successes in the past have led to advances in satellite communications and imagery, precision navigation, stealth, night vision and technologies allowing greatly expanded battlefield awareness. Due to the long-term nature of research results, the R&D PART emphasizes assessment of the process of choosing funded projects and independent assessments of how well the research portfolio is managed.

The assessment indicates that the basic research program has clear purposes of providing options for new weapons systems, helping prevent technological surprise by adversaries, and developing new scientists who will contribute to the DoD mission in the future. DoD can document--through its contracts and grants management regulations, public announcements of award competitions and results from independent review panels--the methodical management of its program. Additional findings include:

1. The grants/contract solicitation, review and award processes are competitive.
2. The program is reviewed regularly by technically capable outside reviewers, which recommend improvements they would like to be implemented. They indicate that the work is of overall high quality.
3. The program has competent planning and management.
4. Earmarking of projects in the program has increased in the past decade and contribute less than the typical research project to meeting the agency's mission.

In response to these findings, the Administration will:

1. Continue to emphasize the use of independent review panels in assessing the performance of the program.
2. 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.

**Program Funding Level (in millions of dollars)**

\* This assessments has not changed since publication in the FY 2004 Budget. For updated program funding levels, see Data File - Funding, Scores, and Ratings.

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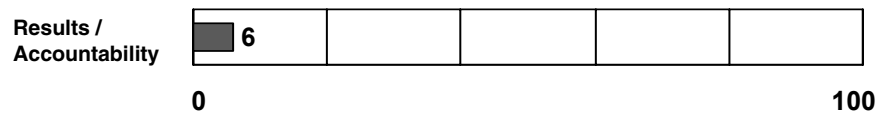
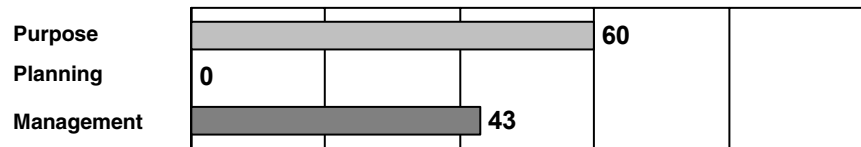
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**Program:** *DoD Small Business Innovation Research / Technology Transfer*

**Agency:** *Department of Defense--Military*

**Bureau:** *Research & Development*



**Key Performance Measures**

**Year Target Actual**

|  |      |      |  |
|--|------|------|--|
| Long-term Measure:<br>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:<br>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:<br>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). | 2004 | 0.15 |  |
|  | 2005 | 0.2  |  |
|  | 2006 | 0.3  |  |
|  | 2007 | 0.5  |  |

**Rating:** *Results Not Demonstrated*

**Program Type:** *Research and Development*

**Program Summary:**

The Department of Defense's (DoD's) Small Business Innovation Research and Small Business Technology Transfer programs supply funds to small businesses (in the latter case, in conjunction with non-profit research institutions) to develop products that help DoD defend the country.

The assessment found that the program:

- Provides funds to small businesses but has poor controls on unproductive spending
- Continues to provide funding to companies with track records of poor performance;
- Overestimates commercial successes resulting from Federal support by treating additional investment in the same way as product sales.

In response to these findings, the Administration will:

1. Tighten eligibility requirements for accepting proposals from companies and individuals that repeatedly fail to sell resulting products in the marketplace.
2. Change the way companies' past performance is assessed to ensure that it more closely matches the intent of the law.
3. Look for ways to budget explicitly for the program's administrative costs.
4. Seek to get highly successful awardees to enter the mainstream of Defense contracting.

**Program Funding Level (in millions of dollars)**

|                    |                      |                      |
|--------------------|----------------------|----------------------|
| <b>2003 Actual</b> | <b>2004 Estimate</b> | <b>2005 Estimate</b> |
| 963                | 1,100                | 1,133                |

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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                    |                |               |   |                |                | <b>DATE</b><br>February 2004 |                |
|---|----------------|---------------|---|----------------|----------------|------------------------------|----------------|
| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA1 Basic Research |                |               | <b>R-1 ITEM NOMENCLATURE</b><br>Defense Research Sciences<br>PE 0601101E,R-1 #2 |                |                |                              |                |
| <b>COST (In Millions)</b>   | <b>FY 2003</b> | <b>FY2004</b> | <b>FY2005</b>   | <b>FY 2006</b> | <b>FY 2007</b> | <b>FY 2008</b>               | <b>FY 2009</b> |
| Total Program Element (PE) Cost   | 171.383        | 139.434       | 143.729   | 146.565        | 148.723        | 151.339                      | 153.893        |
| Bio/Info/Micro Sciences BLS-01  | 77.733         | 43.855        | 63.437  | 77.679         | 79.029         | 78.948                       | 79.843         |
| Information Sciences CCS-02   | 20.306         | 21.194        | 23.791  | 23.592         | 23.565         | 23.547                       | 23.528         |
| Electronic Sciences ES-01   | 17.568         | 26.449        | 25.465  | 21.809         | 22.678         | 25.416                       | 27.118         |
| Materials Sciences MS-01  | 55.776         | 47.936        | 31.036  | 23.485         | 23.451         | 23.428                       | 23.404         |

**(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 Futures; 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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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>             |   | DATE<br>February 2004 |
| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA1 Basic Research | R-1 ITEM NOMENCLATURE<br>Defense Research Sciences<br>PE 0601101E, R-1 #2 |                       |

(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) <b><u>Program Change Summary:</u></b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|--|-----------------------|-----------------------|----------------------|
| Previous President's Budget                                    | 199.030               | 151.029               | 143.522              |
| Current President's Budget                                     | 171.383               | 139.434               | 143.729              |
| Total Adjustments  | -27.647               | -11.595               | 0.207                |
| <br>   |                       |                       |                      |
| Congressional program reductions                               | 0.000                 | -35.495               |                      |
| Congressional increases  | 0.000                 | 23.900                |                      |
| Reprogrammings   | -17.039               | 0.000                 |                      |
| SBIR/STTR transfer   | -10.608               | 0.000                 |                      |

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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                      |  | <b>DATE</b><br>February 2004 |
| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA1 Applied Research | <b>R-1 ITEM NOMENCLATURE</b><br>Defense Research Sciences<br>PE 0601101E |                              |

(U) **Change Summary Explanation:**

- FY 2003                      Decrease reflects below threshold reprogrammings and SBIR transfer.
- FY 2004                      Decrease reflects congressional reductions to biological programs and undistributed reductions offset by congressionally added funds in the areas of nanotechnology, photonics and spin electronics.
- FY 2005                      Increase reflects minor program re-pricing.



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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>             |         |         |         |   |         | DATE<br>February 2004 |         |
| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA1 Basic Research |         |         |         | R-1 ITEM NOMENCLATURE<br>Defense Research Sciences<br>PE 0601101E, Project BLS-01 |         |                       |         |
| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005 | FY 2006   | FY 2007 | FY 2008               | FY 2009 |
| Bio/Info/Micro Sciences BLS-01   | 77.733  | 43.855  | 63.437  | 77.679  | 79.029  | 78.948                | 79.843  |

**(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.

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

|                          |         |         |         |
|--------------------------|---------|---------|---------|
|                          | FY 2003 | FY 2004 | FY 2005 |
| BioComputational Systems | 24.000  | 8.000   | 9.237   |

(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 revolutionary, high-speed methods for use by field commanders to predict biological warfare threats. Requiring only minutes, these computer prediction methods will give warfighters far more information about biological threats faster than today's costly wet-lab technology.

(U) In a related thrust, enhancing biology by using modern computation, the program will develop validated computational models of internal cellular processes, capturing complex gene and protein interactions, and simulation tools, for in-silico analysis, capable of predicting cellular spatiotemporal dynamics. In addition to enabling high-speed methods for commanders to predict threats from biological warfare agents, the program will develop new technologies for the rapid and environmentally safe decontamination of spore-forming bacteria like anthrax in the field.

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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                    |  | DATE<br>February 2004 |
| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA1 Basic Research | <b>R-1 ITEM NOMENCLATURE</b><br>Defense Research Sciences<br>PE 0601101E, Project BLS-01 |                       |

The application realm includes characterization, prediction, and control of biomolecular processes such as those related to pathogens; mechanisms such as circadian rhythms that underlie war fighter performance and well-being in stressed conditions; and design of bio-sensors. This program will also pursue a comprehensive cognitive system that supports rapid analysis and discovery of molecular and cellular level mechanisms underlying pathogenesis relevant to biological threats, and the discovery of potential intervention mechanisms. The modeling and simulation capability will be extensible from cell level to higher levels such as organ, organism, and to collective groups of organisms. In addition, the program will begin leveraging modeling, simulation, and bio-informatics capabilities to explore new methods of biologically inspired computing principles, architecture, and design of robust and reliable information processing and networking systems.

(U) Program Plans:

- Initiate development of a progressively sophisticated suite of dynamic cellular models and architecture for Bio-SPICE (Simulation Program for Intra-Cell Evaluation), which will enable modeling, prediction, and control of last submission “cell model” processes, with continual validation of each model experimentally. The cell modeling and Bio-SPICE will be capable of analysis of hundreds of gene-protein networks and interactions.
- Continue to incorporate spatial models into Bio-SPICE and explore potential reduced-order models capabilities to analyze the non-linear and stochastic dynamics of thousands of interactions for sophisticated analysis of pathogenic agents.
- Investigate scalable and extensible implementation of Bio-SPICE that utilizes a distributed computing architecture supporting a rich set of spatio-temporal models, with the ability to handle vast amounts of experimental data for prediction and analysis.
- Identify candidate biosystem elements for intervention strategies in sporulation, cell cycle control, and other processes in defense against bioagents.
- Investigate the extension of research in knowledge representation and reasoning tools to integrate data and models across multiple scales.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Simulation of Bio-Molecular Microsystems (SIMBIOSYS) | 12.676  | 9.000   | 9.000   |

(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

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

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.

(U) Program Plans:

- Demonstrate high (signal to noise [SNR] ratio > 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 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); demonstrate 10 – 100 X improvement in mixing through MHD and electrokinetic instability mechanism.
- 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.

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|                | FY 2003 | FY 2004 | FY 2005 |
|----------------|---------|---------|---------|
| Bio Interfaces | 9.997   | 5.655   | 10.000  |

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

(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.
- Demonstrate and validate novel nano- and micro-devices for measuring biological systems at the single cell and tissue level.
- Demonstrate and validate novel mathematical tools for analyzing and interpreting complex data sets obtained from complex biological systems.
- Develop mathematical approaches and new microelectronic devices for attacking biological problems including epidemiology and real time identification of biochemical markers.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Biological Adaptation, Assembly and Manufacture | 9.500   | 5.200   | 11.200  |

(U) The Biological Adaptation, Assembly and Manufacturing program will examine the structure, function, and informational basis underlying biological system adaptation, particularly to harsh environments, and the factors employed by the organism to assemble and manufacture complex biological subsystems. The unique stability afforded biological systems in their ability to adapt to wide extremes of physical and endurance (e.g., heat, cold, and sleeplessness) parameters will be examined and exploited in order to engineer stability into biological systems of Defense needs (such as blood or other therapeutics). In addition, the fault tolerance present in biological systems will be exploited in order to assemble and manufacture complex physical and multi-functional systems, both biological and abiotic. Further activity in this area will investigate the communication between adaptive elements within biological systems, including biofilms, as they develop in space and time, and uncovering the fundamental informational and physical architectures that underlie this unique biological property. Applications to Defense systems include the development of highly adaptive, non-linear robust systems as well as chemical and biological sensors.

(U) 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.
- Develop methods for selectively reducing metabolic requirements in a reversible manner following injury to extend the period of survival from injury to initiation of treatment.
- Demonstrate and validate that cells and organisms can be engineered to respond 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 for designing and using biological molecules to assemble functional opto-electronic bandgap materials.
- Develop methods to heal limb-threatening wounds without loss of function through blastema formation and multiple tissue regeneration.

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- Demonstrate the adaptation of bacteria to the digestion of cellulose in disaccharides to enable the ability to use cellulose (e.g., grass) as nutrition.

|                          | FY 2003 | FY 2004 | FY 2005 |
|--------------------------|---------|---------|---------|
| Nanostructure in Biology | 9.560   | 9.000   | 12.000  |

(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. The tools and approaches developed under this program will also have a significant impact in a variety of critical, non-biological Defense technologies that rely on phenomena occurring at the nanoscale level. For example, the 3-D Atomic Resolution Imaging program will develop new instrumentation, computational tools and algorithms for real-time, atomic level resolution, 3D static or dynamic imaging of molecules and nanostructures. This new information about biomolecules will provide important new leads for the development of threat countermeasures, biomolecular sensors and motors, and molecular interventions to maintain human performance in the battlefield. This tool will help with detailed knowledge of doping profiles and defects. It might be possible to use these techniques to measure and control individual atoms or spins. In addition, research will be conducted in the interaction, at the nanoscale, of biotic and abiotic materials and functions.

(U) Another aspect of this program will examine the use of nanostructured magnetic materials to understand and manipulate cells and tissues, enhancing their capabilities to serve as sensors and/or regulatory pathways. The Bio-Magnetics Interfacing Concepts (BioMagnetICs) program will explore nano-scale magnetism as a novel transduction mechanism for the detection, manipulation and actuation of biological function in cells and single molecules. The core technologies to be developed will focus on the many technical challenges that must be addressed in order to integrate nano-scale magnetism with biology at the cellular and molecular level, and to ultimately detect and manipulate magnetically “tagged” bio-molecules and cells. These programs will present unprecedented new opportunities to exploit a wide range of bio-functionality for a number of DoD applications including chemical and biological sensing, diagnostics and therapeutics.

(U) Program Plans:

- Demonstrate proof of concept for using nanomagnetism to detect and manipulate individual cells and biomolecules.
- Demonstrate detection of a single electron spin using a cantilever-based magnetic resonance force microscope.

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- Develop and demonstrate biocompatible, nanomagnetic tags, sensors, and tweezers that will enable magnetics based detection, manipulation, and functional control of single cells and biomolecules.
- Demonstrate single nuclear spin sensitivity.
- 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.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Human Assisted Neural Devices (formerly Brain Machine Interface) | 12.000  | 7.000   | 12.000  |

(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.

(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 working device or prosthetic.
- Explore new methods, processes, and instrumentation for accessing neural codes non-invasively at appropriate spatiotemporal resolution to provide closed-loop control of a peripheral device.
- Demonstrate real time control under relevant conditions of force perturbation and cluttered sensory environments (e.g., recognizing and picking up a target and manipulating it).



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

- Not Applicable.

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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA1 Basic Research |         |         | R-1 ITEM NOMENCLATURE<br>Defense Research Sciences<br>PE 0601101E, Project CCS-02 |         |         |                       |         |
| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Information Sciences CCS-02  | 20.306  | 21.194  | 23.791  | 23.592  | 23.565  | 23.547                | 23.528  |

(U) **Mission Description:**

(U) This project supports scientific study and experimentation on new computational models and mechanisms for communication for long-term national security requirements. This project is also exploring innovative approaches to the composition of software, novel means of exploitation of computer capabilities, practical logical and heuristic reasoning by machine and the development of enhanced human-computer interface technologies.

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

|   |         |         |         |
|---|---------|---------|---------|
|   | FY 2003 | FY 2004 | FY 2005 |
| Computer Exploitation and Human Collaboration | 20.306  | 21.194  | 23.791  |

(U) The Computer Exploitation and Human Collaboration program will develop information processing technologies that allow warfighters and commanders to interact with computers in an intuitive and transparent fashion, and enable collaborations as well as intelligent exchange of information in a seamless manner. Architectures for software agents (including mobile code), redesign of classical computer operating systems, and secure exchange of information over insecure channels are some of the technical challenges in this area. Database currency and management of dynamically changing state are the important areas of research in pervasive computing. This program will explore new human-machine interaction paradigms, where the warfighter's or commander's goals and capabilities are reasoned about and used to drive the interaction. Research will address information overload and simplify user interfaces to effectively enhance military performance by providing concise, salient situation awareness. The creation of powerful multi-agent systems and tools for effective decision-making and analysis in complex multi-participant environments will also be addressed. High-performance, user-centered interfaces, which will be capable of understanding the warfighters' and commanders' combined natural communication and activity patterns, will also be explored. In particular, fundamental technology for integration of information expressed in different modalities will be developed. Overall, the program will provide vastly expanded power and improved efficiency of interaction for a wide range of military tasks and environments.

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(U) In the last two decades, research on machine intelligence has revealed that many reasoning problems have inherent computational complexity. More sophisticated heuristic approaches are needed to deal effectively with the complexity problem. Research in Real-World Reasoning will develop foundational technologies and tools necessary to enable effective, practical machine reasoning about complex, large-scale problems. The program will pursue innovative techniques in reasoning algorithms in terms of scale of the problems, speed of response, and correctness. This research will push the envelope of deep reasoning in decision-making by systematically taking into account interaction amongst multiple teams of warfighters, robots, and weapon systems in strategic settings with each team having different or varying goals. Among the key elements needing investigation are technologies for effective, practical inferential reasoning over information of real-world complexity and uncertainty. Novel paradigms for learning from experience and for capturing events and actions that affect the final outcome of a situation or scenario will be addressed. The difficult research challenges to be addressed by the program include the 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 and always does something reasonable; and appropriate metrics for measuring cognitive behavior and performance.

(U) Program Plans:

- Develop new forms of human-computer interaction that enable human and computers to work as synergistic teams.
- Investigate an adaptive visual and audio processing and display capability to maximize pertinent information conveyance that improves perception comprehension, retention, inference and decision-making.
- Explore cognitive models for integrating users' natural communication modalities (e.g., spoken language, gesture, and gaze) for a new class of interfaces.
- Develop adaptive multimodal processing techniques tailored to the user, task, and environment, assessing performance and usability advantages within multimodal systems developed in the program.
- Establish data-type standards for multimodal input devices (in support of plug-and-play and system-independent design).
- Develop methods for combining statistical and knowledge-based reasoning algorithms.
- Develop high performance reasoning techniques and knowledge representation methods that handle rapid changes in information, as well as uncertainty.
- Develop hybrid and integrated reasoning tools to overcome limitations and shortfalls in current reasoning techniques.
- Explore scalable, high-performance reasoning focusing on propositional systems and methods for temporal reasoning with uncertainty.

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- Evaluate algorithms to find the Nash equilibrium solution and/or the dominant plan from a given set of plans for a variety of reasoning tasks such as effective coalition formation.
- Develop strategic reasoning tools to aid decision-making in complex environments, systematically incorporating information, incentives and goals in a distributed environment.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005 | FY 2006  | FY 2007 | FY 2008               | FY 2009 |
| Electronic Sciences ES-01  | 17.568  | 26.449  | 25.465  | 21.809   | 22.678  | 25.416                | 27.118  |

(U) **Mission Description:**

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

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

|                         |         |         |         |
|-------------------------|---------|---------|---------|
|                         | FY 2003 | FY 2004 | FY 2005 |
| University Opto-Centers | 10.083  | 12.131  | 8.572   |

(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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Semiconductor Technology Focus Centers | 6.158   | 5.500   | 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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Molecular Photonics(MORPH) (formerly Supermolecular Photonics Engineering) | 0.000   | 5.168   | 6.893   |

(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 thermal stability, environmental chemistry tolerance (O<sub>2</sub>, H<sub>2</sub>O, etc) and photochemistry.



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

|                             | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------|---------|---------|---------|
| Advanced Photonics Research | 1.327   | 2.450   | 0.000   |

- (U) Program Plans:
- This program continues research in photonic composites and device fabrication.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Photonics Technology Access Program (PTAP) | 0.000   | 1.200   | 0.000   |

(U) The PTAP 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.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005 | FY 2006  | FY 2007 | FY 2008               | FY 2009 |
| Materials Sciences MS-01   | 55.776  | 47.936  | 31.036  | 23.485   | 23.451  | 23.428                | 23.404  |

**(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 2003 | FY 2004 | FY 2005 |
| Nanoscale/Bio-molecular and Metamaterials | 7.912   | 8.486   | 14.051  |

(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.
- Exploit an understanding of properties that are dominated by surface behavior to develop materials with increased thermal conductivity, biocidal properties, and phonon capture.

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- 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.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Engineered Bio-Molecular Nano-Devices and Systems | 5.000   | 7.200   | 10.985  |

(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.

|                                      | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| Spin Dependent Materials and Devices | 14.000  | 12.000  | 6.000   |

(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.

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

- (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.

|                  | FY 2003 | FY 2004 | FY 2005 |
|------------------|---------|---------|---------|
| Spin Electronics | 15.000  | 12.750  | 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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Ultra Performance Nanotechnology Center | 3.000   | 0.000   | 0.000   |

- (U) Program Accomplishments:
- Continued efforts in ultra-performance nanotechnology and identified specific DoD targets.

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|                                       | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------------|---------|---------|---------|
| Joint Collaboration on Nanotechnology | 1.800   | 1.700   | 0.000   |

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

|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Center for Nanostructure Materials | 0.400   | 0.000   | 0.000   |

- (U) Program Accomplishments:
- Initiated efforts to develop novel nanostructured materials.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Nanotechnology Research and Training Facility | 2.300   | 0.000   | 0.000   |

- (U) Program Accomplishments:
- Initiated a new center to provide a multi-disciplinary research environment and training facility for graduate.

|                                     | FY 2003 | FY 2004 | FY 2005 |
|-------------------------------------|---------|---------|---------|
| Life Science Education and Research | 5.000   | 0.000   | 0.000   |

- (U) Program Accomplishments:
- Explored the potential of a diverse array of multidisciplinary life science programs, ranging from molecular biology to ecology to contribute new technological capabilities for defense.

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|                       | FY 2003 | FY 2004 | FY 2005 |
|-----------------------|---------|---------|---------|
| Molecular Electronics | 1.364   | 0.000   | 0.000   |

- (U) Program Accomplishments:
- Initiated design concepts for the integration of molecular scale electronics for molecular circuits.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Joint Collaboration on Nanotechnology and Biosensors | 0.000   | 3.000   | 0.000   |

- (U) Program Plans:
- Fund a consortium of university researchers to investigate the potential application of nanotechnology for advanced biosensor developments.

|                            | FY 2003 | FY 2004 | FY 2005 |
|----------------------------|---------|---------|---------|
| Nano- and Microelectronics | 0.000   | 2.800   | 0.000   |

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

- (U) Program Plans:
- Demonstrate computing with molecular-scale structures – i.e., nanometer-scale structures.
  - Characterize and organize nanometer-scale materials.

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

- Not Applicable.

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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                      |                |               |   |                |                | <b>DATE</b><br>February 2004 |                |
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| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA2 Applied Research |                |               | <b>R-1 ITEM NOMENCLATURE</b><br>Computing Systems and Communications Technology<br>PE 0602301E, R-1 #12 |                |                |                              |                |
| <b>COST (In Millions)</b>   | <b>FY 2003</b> | <b>FY2004</b> | <b>FY2005</b>   | <b>FY 2006</b> | <b>FY 2007</b> | <b>FY 2008</b>               | <b>FY 2009</b> |
| Total Program Element (PE) Cost   | 390.607        | 334.696       | 342.614   | 408.070        | 470.866        | 503.595                      | 535.638        |
| Intelligent Systems and Software ST-11  | 41.373         | 43.492        | 43.735  | 49.775         | 74.761         | 76.022                       | 67.041         |
| High Performance and Global Scale Systems ST-19                                     | 121.391        | 72.188        | 50.236  | 75.000         | 75.000         | 75.000                       | 100.000        |
| Information Assurance and Survivability ST-24                                       | 31.773         | 46.117        | 52.513  | 65.474         | 63.283         | 77.855                       | 99.968         |
| Asymmetric Threat ST-28   | 79.163         | 0.000         | 0.000   | 0.000          | 0.000          | 0.000                        | 0.000          |
| Language Translation ST-29  | 42.848         | 57.201        | 44.972  | 35.767         | 35.945         | 36.196                       | 40.826         |
| Learning and Reasoning ST-30  | 15.198         | 60.503        | 91.173  | 112.535        | 120.761        | 131.858                      | 124.399        |
| Communications, Interaction and Cognitive Networks ST-31                            | 24.180         | 34.140        | 32.433  | 36.069         | 59.833         | 58.570                       | 50.512         |
| Computing Foundations ST-32   | 8.282          | 17.583        | 27.552  | 33.450         | 41.283         | 48.094                       | 52.892         |
| Knowledge Representation and Reasoning ST-33  | 26.399         | 3.472         | 0.000   | 0.000          | 0.000          | 0.000                        | 0.000          |

**(U) Mission Description:**

(U) The Computing Systems and Communications Technology program element is directed toward the application of advanced, innovative computing systems and communications technologies. Cognitive Information Processing Technology will be 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.



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(U) The Intelligent Systems and Software project develops new technology for software creation, processing and database management. It promises significantly improved software for systems that produce, store, and analyze information about battlespace operations. Efforts will develop 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 more cost-effective microsystems, associated software technologies, advanced mobile information technology and prototype experimental applications critical to defense operations.

(U) The Information Assurance and Survivability project is developing the technology required to make emerging information system capabilities (such as wireless and mobile 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 apply new software database management and human computer interaction technologies to provide fundamentally new capabilities of critical importance for a wide range of national security needs. This will enable advanced information technology to (a) automatically exploit large volumes of speech and text in multiple languages; (b) revolutionize human-computer interaction via using spoken and written English and foreign languages; (c) more effectively accomplish computing and decision-making tasks in stressful, time sensitive situations; and (d) become active, autonomous agents/assistants to the warfighter by collecting, filtering, synthesizing and presenting information in a timely and relevant form.

(U) The Learning and Reasoning project will develop technologies that enable systems to learn and draw on their accumulated experience by applying knowledge gained through such experience to improve performance. These technologies will lead to systems demonstrating increased self-reliance, self-adaptive reconfiguration, intelligent negotiation, cooperative behavior, and survivability with reduced human intervention. Cognitive systems will comprise three primary types of processes: reactive, deliberative and reflective. Each of these will be improved through experiential learning.

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(U) The Communications, Interaction and Cognitive Networks project will dramatically improve warfighter effectiveness by: (1) developing revolutionary methods for users to interact with and direct cognitive systems (and the physical sensors and effectors they control) and (2) enabling large-scale collections of cognitive systems to interact with one another in support of user objectives. Specifically, this project will develop technologies for creating systems capable of instruction, guidance, and persuasion using all forms of natural communication; technologies enabling systems to detect and assess the user’s cognitive state and adapt to optimize understanding and effectiveness of the user; and high-level languages for rapid but precise specification of complex behavior in response to mission demands, such as configuration of sensor networks.

(U) The Computing Foundations project will develop novel system-level solutions through the intelligent integration of cognitive capabilities built on robust software and hardware infrastructure. Systems with humanlike capability will integrate the cognitive capabilities of reasoning, learning, explaining, ability to be advised, self-awareness and coping robustly with surprise. These aspects of intelligence will be combined in innovative and powerful ways using new cognitive architectures. Overall this element seeks to make fundamental scientific and mathematical improvements in our understanding of and ability to create information and computing systems.

(U) The Knowledge Representation and Reasoning project is central to the creation of a new class of computational systems – Cognitive Computing Systems. These novel computer-based systems will reason, learn, and respond intelligently to things that have not been previously programmed or encountered. This will be accomplished by creating unique and powerful new abilities for computers to perceive and understand the world, and to reason intelligently with the results of this kind of perception. This program will develop novel and effective technologies for representing knowledge of the world in computer-processable form. This project focuses on two groundbreaking research areas that will develop core cognitive capabilities essential to a cognitive information processing system.

|  |                       |                       |                      |
|--|-----------------------|-----------------------|----------------------|
| (U) <b><u>Program Change Summary:</u></b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
| Previous President’s Budget                                    | 409.256               | 404.859               | 479.119              |
| Current President’s Budget                                     | 390.607               | 334.696               | 342.614              |
| Total Adjustments  | -18.649               | -70.163               | -136.505             |

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|                                  | <u><b>FY 2003</b></u> | <u><b>FY 2004</b></u> |
|----------------------------------|-----------------------|-----------------------|
| Congressional program reductions | 0.000                 | -76.590               |
| Congressional increases          | 0.000                 | 6.500                 |
| Reprogrammings                   | 0.110                 | -0.073                |
| SBIR/STTR transfer               | -18.759               | 0.000                 |

**(U) Change Summary Explanation:**

- FY 2003                      Decrease reflects SBIR transfer and below threshold reprogrammings.
  
- FY 2004                      Decrease reflects congressional program reduction to terminate Information Awareness Office activities in Project ST-28, offset by congressional adds for Through-Wall Radar Imaging, Secure Group Communications and the Counterterrorism Information Initiative.
  
- FY 2005                      Decrease reflects termination of Project ST-28 in response to congressional action and repricing of cognitive computing programs in Projects ST-31 and ST-32.

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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA2 Applied Research |         |         | R-1 ITEM NOMENCLATURE<br>Computing Systems and Communications Technology<br>PE 0602301E, Project ST-11 |         |         |                       |         |
| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Intelligent Systems and Software ST-11                                       | 41.373  | 43.492  | 43.735   | 49.775  | 74.761  | 76.022                | 67.041  |

(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. 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. First, they accelerate the design of complex Command, Control, Communications and Computation Intelligence, Surveillance and Reconnaissance (C<sup>4</sup>ISR) systems. By formalizing descriptions of semantics, performance, and resource levels, they save programming time. By developing design tools to use those formalisms to assemble systems, they save developers time. Second, they enable field integration of legacy systems by providing general-purpose tools. These tools use the formalisms to search for, browse, display, and combine services available to a command center.

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

|  |         |         |         |
|--|---------|---------|---------|
|  | FY 2003 | FY 2004 | FY 2005 |
| Advanced Human-Computer Interaction for Robust Sensor Exploitation | 0.000   | 0.000   | 3.000   |

(U) The Advanced Human-Computer Interaction for Robust Sensor Exploitation program will develop new interactive mechanisms for analysts and commanders to interact with sensed data. The objective is to facilitate rapid manipulation, correlation, presentation and planning. The program develops new visualization concepts including immersive interactive visualization, interactive temporal data mining, acoustic, haptic and gesture interfaces, and configurable presentation concepts. They will allow “game-like” interactivity with sensor databases, providing rapid feedback to permit what-if exploration of target hypotheses. This program enables more comprehensive utilization of multiple data sources and data feeds. This in turn accelerates certain critical functions: (1) locating challenging targets; (2) processing situational awareness data; (3) interpreting context and intent; and (4) mining historic data for trends. The program particularly enables retrospective, multi-source analysis to understand the historical context of unanticipated events.

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- (U) Program Plans:
- Acquire a diverse set of all-source (radar, optical, acoustic, SIGINT) data from observations of training exercises.
  - Register and align the data to a common reference frame, and store in a laboratory repository.
  - Install prototype tools in the laboratory.
  - Evaluate prototypes for novelty, effectiveness, and compatibility.
  - Select the most promising tools for further development.
  - Assess performance of upgraded tools in terms of coverage rate, error rate, and confidence.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Advanced Target Identification and Classification | 0.000   | 0.000   | 4.500   |

(U) The Advanced Target Identification and Classification (ATIC) program will develop new sensor exploitation aids to enable detection of targets in high-volume sensor feeds with minimal human support. ATIC supports very large target decks (thousands of target types) with high identification performance and very low false alarm rates. It is developing a calculus of variation to account for target variability within a target deck. The program supports appropriate interactions with humans-in-the-loop. ATIC features robust bounds on target classification performance and techniques for on-the-fly training or recognition systems. It promises improved speed and accuracy of target detection, recognition and identification in high volume sensor imagery. The program will dramatically reduce sensor-to-shooter timelines, allowing dynamic target engagement of relocatable and moving targets, and will enable future autonomous hunter-killer weapon concepts. Manpower burdens and requirements for human analysis of sensor data will be reduced, allowing humans to focus on the most critical or ambiguous target calls. Increased targeting flexibility and wide-area robust situational awareness that more fully describes the capabilities of surface targets will be realized.

- (U) Program Plans:
- Develop statistical models of target variability, including shape, surface material, and emissions.
  - Extend high-fidelity signature generation software (both optical and radio frequency) to evaluate sensitivities of signatures to target variations.
  - Identify stable features that distinguish among target type but are insensitive to expected target variations.

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- Define a test set of regular and irregular military vehicles.
- Collect data from sample vehicles using a variety of standoff sensors (radar, optical) in a variety of environments.
- Verify that the selected features provide robust target characterization.

|                                   | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Software for Situational Analysis | 14.037  | 7.292   | 0.000   |

(U) Two complementary programs are budgeted in the Software for Situation Analysis thrust: Rapid Knowledge Formation, and High Precision Knowledge Formation.

- The Rapid Knowledge Formation (RKF) program enables subject matter experts who are not Artificial Intelligence (AI) experts to build, share, and reuse large knowledge bases. RKF is developing technologies for evaluation in challenge problem experiments in tactical ground combat. Technology hurdles include: direct knowledge entry by non-AI experts; coordinating entry of possibly overlapping and inconsistent knowledge by geographically distributed individuals; and achieving a knowledge entry rate by people untrained in AI at twice the rate of today's AI expert. Knowledge entry R&D is focused on techniques for natural language user input into statements of logic. Knowledge coordination focuses on generating new axioms. (Axiom creation techniques include reasoning by analogy, reasoning by example, and techniques for combining sets of axioms.) An especially taxing problem is combining axiom sets developed by different sources, into larger, consistent modules. RKF requires creation of large knowledge bases because it aims to solve complex problems. The problems include: detection and identification of evasive and concealed targets; offensive and defensive information operations; and Weapons of Mass Destruction (WMD) capability assessments of terrorist organizations. RKF is delivering a number of sets of knowledge engineering and development tools. These tools will be provided to DoD and government organizations for incorporation in their intelligence and warfare analysis systems.
- The High Precision Knowledge Formation (HPKF) initiative develops tools to build rich, complex, highly specialized knowledge bases needed to support precision tactical operations. Ground warfare tactics exhibit great variety and complexity. They are highly dependent upon complex relationships between natural and man-made elements of the battlefield. HPKF develops tools to construct, maintain, and update knowledge about terrain features, mobility factors, sensor characteristics, weapons effects, and engagement tactics. It encompasses

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combat situations ranging from desert warfare through infantry operations in jungle to urban combat. It enables automated forces and planning systems to achieve precision engagement of hostile ground forces, both mechanized and dismounted.

(U) Program Plans:

- Rapid Knowledge Formation.
  - Assess multi-user (25-50 individual) system design.
  - Conduct Predictive Battlespace Awareness (PBA) challenge problems.
  - Develop proof-of-concept knowledge bases in coordination with end users.
  
- High Precision Knowledge Formation (HPKF).
  - Evaluate ability of a 1 mega-axiom knowledge base to support high-fidelity problem solving methods for situation awareness and tactical command and control.
  - Define tactical air/ground combat challenge problem.
  - Select external decision aids, and prototype export/import of knowledge with those aids.

|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| DARPA Agent Markup Language (DAML) | 21.360  | 10.500  | 10.545  |

(U) The DARPA Agent Markup Language (DAML) program develops military software tools for use on Intelink and other emerging Command and Control Link systems. The program's focus is on developing technologies to enhance interoperability and to extend the reach of the World Wide Web to programs, sensors, and other data sources. It enables agent-based programs to share information through these mechanisms. DAML develops software language that ties the information about a web resource to machine-readable semantics (ontology) that describes both data content and service providers. Planned DAML demonstrations include both the intelligence community (Intelink) and the control of tactical military operations in operational environments. This effort provides new technologies for intelligent integration of information across a variety of heterogeneous military sources and systems in real time. The related DARPA Intelligent Software Toolkit (DIST) initiative provides a set of tools to transform existing intelligence and command/control software. DIST, which enables existing software to operate in network-centric computing environments, uses DAML ontologies and service descriptions. Without these automated tools, the cost of bringing older software systems into network-centric computing environments would be prohibitive. The tools correlate application-specific ontologies to

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shared database schema, construct translators from application data structures to database schema, and build mediators that convert product streams from publishers to subscribers. The plan is to prototype and evaluate the tools within existing CISR support systems. Systems selected for the prototyping will be those featuring high data-rate signal processing, sensor exploitation, and engagement planning applications.

(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.
- Conduct experimental analysis of DAML applications.
- Deploy DAML tools on joint and component command and control interoperability systems of major commands such as Joint Forces Command.
- Prototype DAML tools as support to enhance the use of agents for coalition warfare command and control.
- Prototype suite of additional tools to encapsulate legacy software to support DAML ontologies, logics, and service descriptions.
- Build example mediators to convert data among DAML ontologies, referencing external knowledge bases as necessary.

|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Taskable Agent Software Kit (TASK) | 5.976   | 5.490   | 0.000   |

(U) The Taskable Agent Software Kit (TASK) program develops tools for construction and analysis of advanced multi-agent systems. Target systems are those that realize a global objective through local decisions based on embedded models of the mission, the environment, and interaction with other agents. These tools provide a common engineering foundation for developing high-confidence, agent-based computing solutions to a spectrum of military problems that require robust, scalable, decentralized approaches in dynamically changing environments. Many agent-based systems are currently being built to support militarily relevant applications such as information retrieval and logistics, however, development methods are ad hoc. Developers understand little about how to engineer desirable global behaviors from local, autonomous actions and decisions or about how to mitigate and contain potentially undesirable behaviors, particularly in highly dynamic and uncertain environments. TASK explores methods derived from Control Theory, Decision Theory, and Operations Research for correctly modeling and building agent-based systems. TASK experiments are designed to reveal the qualitative aspects of environments that favor the use of agent-based systems rather than centralized approaches.



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(U) Program Plans:

- Publish initial design and analysis techniques in two focus domains: (a) control and analysis of autonomous vehicles in dynamic environments; and (b) decentralized, competitive resource allocation for logistics.
- Establish a consolidated, open experimental framework based on cooperative autonomous vehicles.
- Employ it for integration and evaluation of agent control, coordination, learning, and adaptation algorithms and analysis techniques.
- Demonstrate and evaluate agent design and analysis techniques on a series of challenge problems characterized by: increasing mission complexity (search to surveillance to targeting); increasing scale (10s to 100s of vehicles); and increasing environment uncertainty (dynamic target behavior to vehicle failures to malicious vehicle behavior).
- Deploy a prototype suite of integrated agent-creation tools with predictable behaviors based on mathematical techniques for modeling and analyzing agent behavior.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Automatic Target Recognition Technology | 0.000   | 8.000   | 8.690   |

(U) The Automatic Target Recognition Technology program develops new sensor exploitation aids to detect targets in high volume sensor data with minimal human support. It supports very large sets of targets (1000's of target types) with high identification performance and very low false alarm rates. It develops modeling methods to account for target variability related to partial damage, design difference, or equipment carried on the vehicle's exterior. The program supports interaction with humans, who supply operational context, guide hypothesis development, and adapt models. The program develops techniques for in-the-field training of models, signatures, and scoring parameters. This allows it to identify vehicle-specific signatures, and develop new target fingerprinting techniques. The program develops new methods to assist humans in achieving precise identification of ad hoc, poorly defined targets. It enables a dramatic reduction in sensor-to-shooter timelines, supporting dynamic target engagement.

(U) Program Plans:

- Obtain a regular supply of data from field and developmental sensors, covering many target types in many 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 1000's 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. Compute statistically significant estimates of performance to compare against the performance analyses.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Information Dissemination and Management | 0.000   | 6.210   | 8.000   |

(U) The Information Dissemination and Management program develops technology to allocate information resources (transmission, storage, and processing) for optimal utilization of data across multiple missions. Program techniques adjust information flows to fit available bandwidth/time for bulk data. Target imagery is adjusted by altering quality, data rate, and time of transmission; streaming data, such as video and ground moving target indications (GMTI), is adjusted by altering quality and rate. Command data, such as waypoints and events, is adjusted by altering time of transmission. The program explores approaches to the reallocation of resources dynamically as tasks arise and network topology and capabilities change. Reallocation is achieved through the use of intermediate storage or intermediate processes (e.g. registration). The program provides real-time sensor-to-shooter resource management to support dynamic operations, including targeting, force protection, and battlespace awareness. Most importantly, it provides information for commanders and weapons when communications resources are oversubscribed during battle conditions. It will provide commanders with the means to respond in real-time to changes in resources due to outages or battle damage.

(U) Program Plans:

- With service partners, identify and obtain a suitable testbed, with supporting data links, databases, application servers, and users.
- Define a class of information architectures that establishes insertion constraints for information management technology.
- Develop and extend real-time resource allocation technology to manage network assets in response to time-varying demands.
- Develop human interfaces to allow controllers to specify information needs, both present and anticipated.
- Insert information management algorithms into the testbed, and stimulate them with increasing levels of subscription.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Rapid Software Composition for Embedded Systems | 0.000   | 6.000   | 7.000   |

(U) The Rapid Software Composition for Embedded Systems program develops technology to permit rapid assembly of heterogeneous C<sup>4</sup>ISR components for execution on complex, highly parallel real time embedded architectures. It explores techniques for rapid parallel code development and optimization, and leverages advanced architectures for development, exploration, and rapid deployment of C<sup>4</sup>ISR components. The program delivers tools and software libraries that allow C<sup>4</sup>ISR systems to be rapidly assembled from discrete, pre-tested components. It will assist developers in assembling and tailoring C<sup>4</sup>ISR systems for mission-specific tasks. In addition, the technology facilitates mapping C<sup>4</sup>ISR system components onto advanced run-time architectures. This will enable high performance operations in limited footprint environments (airborne, tactical vehicle, afloat). The tools created will support rapid development and optimization of new C<sup>4</sup>ISR capabilities using spiral development processes without loss of performance.

(U) Program Plans:

- Identify a set of challenge applications across the spectrum of C<sup>4</sup>ISR 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.
- Verify run-time feasibility and achievement of desired performance.
- Validate the tools and models within the challenge applications.

|                             | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------|---------|---------|---------|
| Semantic Information Fusion | 0.000   | 0.000   | 2.000   |

(U) The Semantic Information Fusion program develops tools to correlate fragments of target location, identity, and behavior information into a composite description of a situation. The program will focus on incorporating data on human activities obtained from human sources, whether

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openly or surreptitiously. Information represented in linguistic terms will combine with physics-based models of visibility, mobility, and access to reconstruct past events, and infer current situations. This effort enables combining human-derived information with products prepared for automated systems. It will permit context-sensitive determination of the sensitivity of inferred information, and invocation of protection mechanisms, at the time of inference.

(U) Program Plans:

- Obtain streams of text information produced by tactical commanders in training operations.
- Employ state-of-the-art entity, date, and relationship extractors to construct symbolic representations of message contents.
- Identify external foundation and contextual knowledge required to correlate material on one entity appearing in different sources.
- Develop symbolic correlation techniques to automatically suggest associations.
- Employ supervised training approaches to improve scoring functions and hypothesis management logic.
- Assess the performance of the technologies on sequestered test data from a variety of sources.

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

- Not Applicable.

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| <b>COST (In Millions)</b>   | <b>FY 2003</b> | <b>FY 2004</b> | <b>FY 2005</b>  | <b>FY 2006</b> | <b>FY 2007</b> | <b>FY 2008</b>               | <b>FY 2009</b> |
| High Performance and Global Scale Systems ST-19                                     | 121.391        | 72.188         | 50.236  | 75.000         | 75.000         | 75.000                       | 100.000        |

(U) **Mission Description:**

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

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

|                                    |                |                |                |
|------------------------------------|----------------|----------------|----------------|
|                                    | <b>FY 2003</b> | <b>FY 2004</b> | <b>FY 2005</b> |
| Responsive Computing Architectures | 59.425         | 55.712         | 50.236         |

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

- The Power Aware Computing and Communications (PAC/C) program is developing an integrated software/hardware power management technology suite comprised of novel techniques that may be applied to all levels of a system from the chip to the system level. Embedded

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military computing systems such as future Land Warrior systems, autonomous devices, distributed sensors, and space sensors have extreme dynamic computational and energy requirements. PAC/C will enable embedded computing systems to reduce energy requirements by ten to one hundred-fold for energy constrained military applications ranging from hand-held computing devices to unmanned aerial vehicles.

- The High Productivity Computing Systems (HPCS) program will provide DoD with significant technology and capability advancements for the national security and industrial communities by filling a high-end tera to petascale computing gap between today's late 1980's based technology High Performance Computing systems and the promise of quantum computing. This program is targeting high end computing, medium to long term, national security missions where U.S. superiority and security is threatened, according to two recent DoD studies. The proposed technology development plan is part of a three-phase program that will extend up to the end of this decade. The three phases are concept study, research and development, and 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 of large scale computing systems; (3) integral hardware, software, application robustness; (4) intrusion resistance; (5) run-time software brittleness; (6) time-to-solution; and (7) cost of developing, operating, and maintaining DoD national security applications. As an example, performance (efficiency) for critical national security applications will be improved by 10-to-40 fold. Early identification of high-end computing application computing 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.
  - Demonstrate 10X power/energy aware reduction techniques across five power aware levels: 1) mission, 2) subsystem/algorithm, 3) software/compilation, 4) operating systems, 5) architecture/devices into the power aware simulator library.
  - Conduct preliminary PAC/C energy simulation/modeling framework concept demonstration.
  - Provide a beta release of the PAC/C energy aware simulator and modeling framework for the PAC/C subscale developers to evaluate.
  - Finalize selection of the power aware technologies to be incorporated and demonstrated for each of the planned power aware subscale demonstration projects which include the following application areas: distributed sensors, space processing, Land Warrior/Objective Force, and communications.
  - Continue the development of the final subscale demonstration projects and provide interim and final demonstrations.

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- High Productivity Computing Systems.
  - Established and implemented the cognitive relaxed computer dialog architecture to support the warfighter in natural language interface with the computer.
  - Perform an industry concept and critical technology assessment review for viable HPCS systems for potential implementation in the (2007 - 2009) timeframe.
  - Release alpha "value-based" productivity metrics and benchmarks to guide future program research and development activities.
  - Address large system brittleness by exploring hardware and software reliability/fault tolerance capabilities, active application software bug tolerance, and intrusion identification and resistance.
  - Explore balanced "productive" system architectures balancing processors, memory, interconnects, software, and programming environments.
  - Downselect viable system solutions and critical technologies to be prototyped; demonstrated and evaluated prior to full-scale implementation.
  - Implement basic and applied software research in the revitalization of high-end computing.

|                             | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------|---------|---------|---------|
| Network Embedded Technology | 33.187  | 16.476  | 0.000   |

(U) The Network Embedded Technology component develops 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. The Network Embedded Technology component is comprised of Networked Embedded Systems Technology and Program Composition for Embedded Systems.

- The Networked Embedded Systems Technology (NEST) program provides robust coordination and synthesis services for networked systems that are subject to extremely tight timing, power, and resource constraints. It supports applications that include micro-electromechanical systems-based fine-grain distributed control applications, sensor networks, and "smart" structures for active acoustic and structural damping. These applications require up to 100,000 simple computing nodes arrayed in a network, serving a common



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purpose. NEST produces reusable software libraries, tools and reference applications that dramatically simplify the development tasks in these environments.

- The Programmable Composition of Embedded Software (PCES) program is developing 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-decisionmaker-to-shooter chain. The reusable code-base, tools and reference applications delivered by PCES more effectively exploit human effort to produce high-quality software that has the adaptability, robustness, and efficiency required by time-critical targeting systems.
- (U) Program Plans:
- Network Embedded Systems Technology.
    - Develop formal modeling and verification techniques for coordination-services and for integrating them.
    - Develop low-cost, Open Experimental Platforms for network embedded software technology.
    - Conduct baseline demonstrations of NEST technology in a variety of environmental monitoring and tracking applications.
    - Demonstrate real-time synthesis of schedules (e.g., for actuator firing sequences) and services (e.g., for localization, route planning) using phase transition-aware constraint solvers.
    - Develop customizable and adaptable solutions for coordination-services for network embedded software technology applications.
    - Develop tools for the automatic composition and verification of application-specific coordination service packages.
    - Demonstrate the synthesis of an optimized coordination service package on the experimental platform.
    - Demonstrate the application design process and evaluate performance of a deployed thousand-node sensor system capable of self-initializing, detecting, tracking and assisting in the pursuit of smart evaders.
  - Program Composition for Embedded Software (PCES).
    - Develop scalable techniques for validation of tactical embedded software by computerized analysis of models of the system.
    - Develop language representation and compilation techniques for fine-grained and coarse-grained; aspect-oriented programming of tactical embedded systems.
    - Develop 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.

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- Develop 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.
- Develop 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.
- Develop catalogs of patterns and pattern languages that formalize the successful techniques associated with developing tactical embedded systems middleware and applications.

|                            | FY 2003 | FY 2004 | FY 2005 |
|----------------------------|---------|---------|---------|
| Autonomous Systems Control | 6.001   | 0.000   | 0.000   |

(U) The Autonomous Negotiation Teams program developed the software technology to resolve time-critical constraints in logistics and mission planning. The technology has enabled designers to build systems that operate effectively in highly decentralized environments, making maximum use of local information, providing solutions that are both good enough and soon enough.

(U) Program Accomplishments:

- Autonomous Negotiation Teams.
  - Demonstrated ability to identify autonomous negotiating teams needed for cooperative flight scheduling and maintenance planning.
  - Demonstrated prototype implementation and evaluation of negotiation in real-time mission planning for Harrier aircraft mission planning and maintenance operations.
  - Demonstrated ability for hierarchical coalition formation in real-time and avoidance of conflict by changing plans.
  - Demonstrated ability to negotiate tasks in a real-time, multiple target tracking problem with requirements of 0.25 ft error, 90 percent probability of disambiguation, and 500-millisecond response time.
  - Demonstrated an integrated utility for the selection of negotiation strategies to meet goals of convergence, optimality, timeliness and stability in changing environments.
  - Demonstrated dynamic re-synthesis of the application under time constraints, using distributed constraint solvers.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Mixed Initiative Control of Automa-Teams (MICA) | 16.678  | 0.000   | 0.000   |

(U) The Mixed Initiative Control of Automa-teams (MICA) program is developing algorithms, software, and modeling and simulation capabilities to perform multi-level planning, assessment and control of distributed, autonomous combat forces. MICA provides a commander with the operational and mission planning tools to select optimal team composition, to perform dynamic tasking and re-tasking of teams, and to generate cooperative routes for autonomous unmanned air vehicles (UAVs) in stressful operational missions, especially suppression of enemy air defenses. The program focuses on collaborative strategies and tactics for these teams under the supervision of a single human operator, with adjustable autonomy determining the degree of human authority desired or required during task execution. Through the exploitation of control science metrics for stability, performance and robustness, these teams of cooperative, autonomous vehicles such as unmanned combat air vehicles will accommodate uncertainty in both the operating environment and in the feedback information, as well as address the presence of an intelligent adversary and fixed and mobile threats in the battlespace. The program is funded in PE 0602702E, Project TT-13, in FY 2004.

(U) Program Accomplishments:

- Developed algorithms and software to assign autonomous combat vehicles to task-oriented teams.
- Developed algorithms and software to assign mission-derived subtasks to each combat vehicle in a team.
- Developed algorithms and software to generate event schedules and collaborative routes for each combat vehicle in a team.
- Defined algorithms and software supporting dialog between human commanders/operators and semi-autonomous entities to communicate recommended courses of action, appropriate feedback information, and decision tuning parameters.
- Deployed an open experimental simulation environment, driven by UAV suppression of mobile air defense elements and incorporating multiple UAV teams and multiple command levels.

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|            | FY 2003 | FY 2004 | FY 2005 |
|------------|---------|---------|---------|
| Networking | 6.100   | 0.000   | 0.000   |

(U) The Networking program developed new paradigms in networking technologies to meet future defense and national security needs. The program created highly robust and rapidly configurable networking capabilities essential for both secure national infrastructure and ad-hoc military networks through key innovations in software and hardware technologies. The results are applicable to wired, wireless and mixed networks. The Networking component was comprised of Active Networks and Ultra High-Performance Networking.

- The Active Networks program investigated the use of smart packet processing to enable new strategies in rapid network service introduction and enhancement.
- The Ultra High-Performance Networking program advanced transparent all-optical networking and gigabit wireless techniques to dramatically enhance bandwidths available to end-applications.

(U) Program Accomplishments:

- Active Networks.
  - Developed and demonstrated: 1) Intrusion Detection and Response (IDR) prototype; 2) Active Network Operating System focused on policy-free security architecture and availability; and 3) the capability to operate within a mobile computing environment.
  - Developed active network techniques for distributed network management, resource control, and distributed network service deployment, configuration, and management.
- Ultra High-Performance Networking.
  - Demonstrated correlation of multi-gigabit per second transfer of radar signal streams from multiple sources.
  - Demonstrated 16-32 video blanket media streams and client side browsers for display of these streams.
  - Designed precision (1cm) network based geo-location system scalable to 100 nodes in an indoor setting.
  - Demonstrated hybrid optical/radio frequency self-healing link with proactive switching at 600 Mbps.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Information Assurance and Survivability ST-24                                | 31.773  | 46.117  | 52.513   | 65.474  | 63.283  | 77.855                | 99.968  |

(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.

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

|                         |         |         |         |
|-------------------------|---------|---------|---------|
|                         | FY 2003 | FY 2004 | FY 2005 |
| Fault Tolerant Networks | 13.557  | 4.191   | 2.000   |

(U) The Fault Tolerant Networks (FTN) program will develop technologies to provide continuous and correct network operation even when attacks are successful. These technologies will reduce the amount of damage sustained during an attack, allowing networks to maintain an acceptable, minimum level of functionality. Technologies for strengthening networks will be developed by introducing fault tolerance capabilities against possible attacks at the network level, emphasizing integrity and availability; and technologies for mitigating potential vulnerabilities associated with denial of service attacks. The most promising of these technologies will be tested in operationally relevant experiments with U.S. warfighters in DARPA's Partners in Experimentation program, which is also budgeted in this project.

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- (U) Program Plans:
- Developed epidemic 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. Explored the relationship between these approaches and developed a unified model for multi-path communication.
  - Demonstrated attack profiling and filtering algorithms that discard a high percentage of DDoS traffic and a low percentage of non-DDoS traffic.
  - Extend an overlay network prototype to integrate boundary security, enforcing overlay separation and preventing leakage of traffic onto the base network.
  - Demonstrate statistical measures that are both efficient and effective at detecting traffic that contributes to a Distributed Denial of Service (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.

|                    | FY 2003 | FY 2004 | FY 2005 |
|--------------------|---------|---------|---------|
| Dynamic Coalitions | 9.942   | 2.009   | 2.000   |

(U) The Dynamic Coalitions program is developing technologies to support the secure creation of dynamic coalitions including the necessary technologies for policy management, group communications, supporting security infrastructure services, data sharing, and joint collaboration spaces. These areas are critical for future warfighting scenarios as outlined by Joint Vision 2020, which states that future military operations will be increasingly conducted jointly, both with multiple branches of the U.S. Armed Forces and with allied and coalition forces, requiring increased levels of interoperability. Further, this effort will build upon recent advancements in wireless networking technologies by investigating technologies to migrate coalition information assurance tools from servers to gateway radios thus placing the functionality directly at the interface, and localizing coalition policy to gateways. The most promising technologies developed under this program will be tested in operationally relevant experiments with U.S. warfighters in DARPA’s Partners in Experimentation program, which is also budgeted in this project.

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- (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.
  - Complete the design and implementation of architecture for scalable trust negotiation that incorporates reusable tickets or tokens so that repetitive, heavyweight trust negotiations are not required for access to every protected resource within a security domain.
  - Develop 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.
  - Develop low-cost IP-Sec devices that could be deployed to every coalition desktop or tactical work station, providing a low-cost classified coalition networking solution.

|                             | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------|---------|---------|---------|
| Partners in Experimentation | 4.043   | 7.844   | 5.843   |

(U) The Partners in Experimentation program will conduct security technology experimentation with operational military and coalition partners. Operational experimentation will provide valuable feedback to the security technology research and development process which will demonstrate to operational personnel the benefits of advanced technology, and accelerate technology transition.

- (U) Program Plans:
- Demonstrate secure group communication capability for informal trust relationships.
  - Demonstrate multi-application cross-domain information sharing capability.
  - Provide the capability for cross-domain information sharing for an interoperability demonstration.
  - Demonstrated network monitoring and Distributed Denial of Service (DDoS) countermeasures.
  - Demonstrated identity-based encryption techniques to secure email in a multi-organization collaborative environment.



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- Construct and demonstrate 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.

|                                  | FY 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Next Generation Optical Networks | 0.000   | 8.671   | 7.521   |

(U) The Next Generation Optical Networks program will revolutionize the operation, performance, security, and survivability of the United States' critical inter-networking system by leveraging technology developed in DARPA photonics component and secure networking programs. These goals will be accomplished through a transformation in fundamental networking concepts that form the foundation upon which future internetworking 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. Integration of terrestrial fiber optic lines with free-space optical and RF wireless transport systems, and establishment of a CONUS wide testbed with mobile overseas nodes will enable development, experimentation, and validation of new hardware, software, and network architecture concepts. This effort will deliver the high-performance internetworking 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) The Millimeter Wave Networks project is to develop new technology to make upper millimeter wave (MMW) region affordable for proliferated use in an operational environment. Current approaches to Low Probability of Exploitation systems are inherently constrained by the inherent requirement to radiate energy and create high levels of signal to noise ratio in order to communicate increasing amounts of information. This project leverages the unique characteristics of the 60GHz band, which attenuates radio signals very rapidly due to absorption, to develop

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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. Existing systems are vulnerable to intelligent jamming by high power sources at relatively long ranges. Oxygen absorption limits the ability of distant jamming systems to create interference level signals within the network area. The program will also develop and exploit new concepts for the development of RF components to reduce cost and size. These concepts have been developing through other DARPA technology programs, and include quasi-optical, special combining, resonant tunnel device, and related technologies. The program will develop network components that can be operated anywhere in the world with a highly controllable detection radius. These technologies will also be applicable to unmanned, space and aircraft based uses.

(U) Program Plans:

- 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.
- Demonstrate the ability to manage frequency and enforce low probability of detection limits.
- 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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Dynamic Quarantine of Worms (formerly known as the Malicious Code Analysis) | 2.231   | 13.543  | 14.807  |

(U) The goal of the Dynamic Quarantine of Worms is to develop dynamic quarantine defenses for U.S. military networks against large-scale malicious code attacks such as computer-based worms. The ever-growing sophistication of the malicious code threat has surpassed the ability of commercial industry to address this problem. 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 worm-based attacks against military networks, provide advanced warning to other DoD enterprise networks,

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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. (Further, the program will develop defenses against cyber attacks on mobile ad hoc network (MANET) systems that can to sense failures and attacks and auto-recover in real-time. Technical approaches include the automatic and dynamic quarantine response and forensics analysis of malicious code that will employ static and dynamic code analysis for program understanding. Defense Against Cyber Attacks on MANETs project under this program will develop the means to monitor and control the trustworthiness of distributed tactical applications used in network centric warfare operations. This program will develop technology to ensure network centric warfare systems are able to fulfill their mission in spite of cyber attacks such as computer worms unleashed on MANETs and runtime failures.

(U) Program Plans:

- Develop automatic detection and quarantine mechanisms.
- Provide real-time and off-line analysis capabilities.
- Develop network appliance and host-based detection/response network interface devices.
- Verify integrated system capabilities.

|                     | FY 2003 | FY 2004 | FY 2005 |
|---------------------|---------|---------|---------|
| Trustworthy Systems | 0.000   | 9.859   | 9.908   |

(U) The goal of the Trustworthy Systems program is to address information assurance of tactical systems in complementary strategies, including to build trustworthy information processors (TIP), as the basis for running trustworthy systems. The Trusted Information Processors (TIP) Project under this program will develop the ability to design systems that can be provably verified as trustworthy despite complexity of millions of transistors and millions of lines of code. TIP will develop prototypes in partnership with other government agencies responsible for follow-on development of such capabilities, as well research publication and demonstration prototypes that lend themselves to commercial production that dramatically offsets military acquisition costs. Other aspects of ensuring trustworthiness in network centric warfighting architectures such as validating users, adapting mission goals, and reconfiguring nodes and platforms for optimal mission execution as a result of changes that may occur in the trustworthiness of the network will be explored.

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- (U) Program Plans:
- Explore processors capable of fully encrypting the entire state of computation at each step.
  - Design and fabricate an integrated circuit chip that can be verified to have everything in the design, without malicious inclusions.
  - Design and produce a microprocessor system that keeps all state information outside the arithmetic logic unit cryptographically signed at all times.
  - Design a processor with each component fully validated via formal mathematical proofs to faithfully execute high level instructions.
  - Produce a malice tolerant architecture capable of consistently producing correct results, even if most components are compromised.
  - Produce a computer verified proof that the malice tolerant architecture will consistently produce correct results under worst cases.
  - Develop fundamental principles and approaches to trustworthy control and emergent survivable behavior.
  - Identify dynamic indicators of system unreliability and insecurity.
  - Develop approaches for real-time trustworthy monitoring and control.
  - Develop trustworthy co-processors for adaptive control and dynamic provisioning of computational resources.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| DARPA Future Information Assurance Initiatives | 0.000   | 0.000   | 3.737   |

(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 21<sup>st</sup> century transformation of the U.S. military will be more dependent on information technology for C<sup>4</sup>ISR 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 C<sup>4</sup>ISR 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 on which the future U.S. military will be heavily dependent 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

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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. The DARPA Future Information Assurance Initiatives will identify promising technologies to continue to push the state of the art. Distinct programs within this project will be created for promising technologies as they are identified for further focused development.

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

|               | FY 2003 | FY 2004 | FY 2005 |
|---------------|---------|---------|---------|
| Control Plane | 0.000   | 0.000   | 3.597   |

(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

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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 2003 | FY 2004 | FY 2005 |
|------------|---------|---------|---------|
| CyberPanel | 2.000   | 0.000   | 0.000   |

(U) The Cyber Panel Program developed capabilities to help defend mission-critical information systems by monitoring them for signs of cyber attack, and allowing operators to manage the operation of system security and survivability features to avert or counter developing attack situations. Intrusion assessment technologies were developed to detect security threats through correlation and analysis of observed/reported activities. Autonomic response capabilities were developed to react in milliseconds to block or withstand many classes of known and unknown attacks. Monitoring and response components were developed that allow warfighters to observe the performance, health and threat state of mission critical information systems, project the likely impact of reported cyber attacks on system operation, assess possible defensive actions, and carry them out.

(U) Program Plans:

- Investigated methods for augmenting passive intrusion detection sensors with capabilities to actively probe for additional attack information.
- Explored techniques for improving the effectiveness of auto-response defenses with limited intelligence about attack models.

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- Conducted experiments to determine the usability of general-purpose anomaly detection algorithms to monitor a large, complex military software system.
- Combined selected Cyber Panel technologies into an integrated demonstration prototype incorporating cyber attack detection, correlation, assessment, and response capabilities.

|                      | FY 2003 | FY 2004 | FY 2005 |
|----------------------|---------|---------|---------|
| Asymmetric Firewalls | 0.000   | 0.000   | 3.100   |

(U) The Asymmetric Firewalls program develops devices that can act as firewalls for wide-area networks. Asymmetric flows are traffic flows (groups of data packets) between a sender and receiver where the outbound packets and the inbound packets do not follow the same route. Forty to sixty percent of all traffic on the Internet (and on military networks) flows asymmetrically. There is currently no technology capable of providing firewalls on wide area networks because current firewalls must be able to monitor all traffic in both directions to work correctly.

(U) Program Plans:

- Develop protocol analyzers for simultaneous decoding of packet, session, flow, and application layer data.
- Develop high-speed distributed cueing system for use by distributed and independent firewalls.
- Develop software asymmetric firewalls for small networks.
- Develop high speed asymmetric firewalls for networks.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Language Translation ST-29   | 42.848  | 57.201  | 51.972   | 35.767  | 35.945  | 36.196                | 40.826  |

**(U) Mission Description:**

(U) This project will develop and test powerful new Human Language Technology (HLT) that will provide critical new 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 Accomplishments/Planned Programs:**

|  |         |         |         |
|--|---------|---------|---------|
|  | FY 2003 | FY 2004 | FY 2005 |
| Situation Presentation and Interaction | 8.232   | 10.869  | 6.400   |

(U) There are two programs involving *human-machine* communication:

- The Compact Aids for Speech Translation program, formerly the Babylon 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 prototypes of the technology relying on simple dictionaries and phrases have been deployed on a test basis to Afghanistan. Future versions will offer more sophisticated, flexible and fluid translation and paraphrasing capability that will be more robust and conducive to normal human conversations.
- The Symphony program is an applied follow-on effort to the Communicator Program, emphasizing technology transition to the military, adaptability, and scalability of the Communicator Galaxy Architecture for automatic dialogue in support of C2 (Command and Control)



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applications. Technologies to be emphasized include human stress adaptation, prosody, and system reliability in military environments. The program will centerpiece six technology insertion projects supporting all services.

(U) Program plans:

- Compact Aids for Speech Translation.
  - Established baseline hardware design for handheld translation technology.
  - Developed and evaluated initial DARPA 1+1 Way prototypes which provide limited two-way translation.
  - Conducted multi-lingual data collection in Pashto, Dari, Farsi, Arabic, and Mandarin for contingency operations.
  - Distributed multilingual corpus to R&D community.
  - Upgrade DARPA one-way technology to limited two-way translation.
  - Obtain initial software decision approvals for full-featured DARPA two-way translation.
  - Produce prototype handheld devices for field evaluations and acceptance.
  - Perform initial coordination with U.S. Army PM Soldier for software integration into land warrior Block III (version 3.0).
  - Integrate speech recognition engines into natural language parsers and translators.
  - Receive feedback from evaluators on DARPA two-way technology (deliver patches and fixes); units remain in operational use.
  - Deliver upgraded handhelds (capable of supporting two-way technology) to software developers.
  - Deliver alpha versions of DARPA two-way software for initial user testing.
  - Select set of foreign languages for final development.
  - Populate language digital resource repository at Defense Language Institute.
- Symphony.
  - Develop FA-18 aircraft maintenance mentor prototype to enhance flight mechanic methods.
  - Develop the Battlefield Casualty Reporting System, a dialogue driven process to allow casualty reporting and sworn statements to be collected, automated validation and direct reporting to Decision Authority notification officials.
  - Develop a ship based command and control system to allow officers and crew to query ship system status from any location on the ship, set an alarm for a future change in status, or launch agents to monitor particular sub systems.

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- Create a complete dialogue based interface for information management systems to support system navigation and analytical processes; augment search parameters and dialogue based mentoring to assist the novice analyst or enhance the experienced analyst.
- Conduct a vehicle navigation effort that focuses on the on-the-move environment attacking dialogue base capability in tactical vehicle noise, for the purposes of navigation, command and control and logistical support.
- Initiate evaluation of dialog technologies for the Institute of Justice for use in multilingual detention facilities.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Automated Speech and Text Exploitation in Multiple Languages | 34.141  | 46.332  | 45.572  |

(U) There are three programs involving *human-human* communication:

- Translingual Information Detection, Extraction and Summarization (TIDES) is revolutionizing the way time-critical intelligence is obtained from speech and text by developing technology to enable English-speaking operators and analysts to exploit the huge amounts of foreign speech and text available electronically or in captured documents, but currently unexploitable due to vast volumes and insufficient foreign language skills. TIDES is creating powerful new capabilities for Detection (finding or discovering needed information), Extraction (pulling out key information), Summarization (substantially shortening what a user must read), and Translation (converting foreign language material to English). This 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 swiftly, safely and effectively.
- Effective, Affordable, Reusable Speech-To-Text (EARS) is creating powerful new automatic speech-to-text transcription technology whose output is substantially richer and much more accurate than previously possible. EARS will provide passive listening technology for critical languages and media for a wide range of national security applications. It will enable effective automated transcription from broadcasts, telephone conversations, and multiparty speech.

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- Global Autonomous Language Exploitation (GALE) will develop techniques for discovering critical intelligence by autonomously exploiting enormous volumes of streaming speech and text from around the world (in many languages). GALE will enable machines to analyze, refine, combine, and package information from broadcasts, conversations, newswire, and internet sources; discover trends and deviations; discern operator/analyst interest (from their tasking, actions and reports); and issue critical alerts, reports, and pointers whenever appropriate (without overwhelming the analysts), delivering information in actionable form without requiring the operators or analysts to request it. GALE will build off the successes of both TIDES and EARS.
  
- (U) Program Plans:
  - Translingual Information Detection, Extraction and Summarization (TIDES).
    - Demonstrate capability to detect and track events described in English, Arabic, and Chinese news sources.
    - Demonstrate capability to extract key information (about people, places, organizations, and relationships) from English, Arabic, and Chinese.
    - Demonstrate capability to translate Arabic and Chinese documents into readable English.
    - Develop methods to convert document images to translated text.
    - Develop methods for porting TIDES technology to new languages.
    - Define architecture for a unified text and audio processing (TAP) system that integrates various TIDES technologies.
    - Transition successful components to operational customers.
  
  - Effective Affordable Reusable Speech-To-Text (EARS).
    - 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.
    - Substantially improve the word-error-rate performance of automatic transcription from approximately 50% down to 5-10%.
    - Create automatic metadata extraction algorithms to enrich the resulting transcripts and to make them more readable.
  - Create, demonstrate, and evaluate prototype systems.

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- Global Autonomous Language Exploitation (GALE).
  - Initiate multifaceted effort to develop techniques for discovering critical intelligence autonomously, exploiting huge volumes of streaming speech and text in multiple languages.

|                               | FY 2003 | FY 2004 | FY 2005 |
|-------------------------------|---------|---------|---------|
| Center for Critical Languages | 0.475   | 0.000   | 0.000   |

(U) Provided funding to assist in the development of a Center for Critical Languages.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Learning and Reasoning ST-30   | 15.198  | 60.503  | 84.173   | 112.535 | 120.761 | 131.858               | 124.399 |

**(U) Mission Description:**

(U) In the real-time environment of military operations, networks and systems that can learn, reason, draw on their experience, automatically adapt to maintain their critical functionality, effectively assist their military user, and improve their responses over time, will be crucial to operational success. These technologies 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 sleek, dynamic expeditionary force, it is critical for systems to be more self-sufficient.

(U) The Learning and Reasoning project will develop core technologies that enable computing systems to learn, reason, and draw on their accumulated experience by applying knowledge gained through such experience and then respond intelligently to things that have not been previously programmed or encountered. These technologies will lead to systems demonstrating increased self-reliance, self-adaptive reconfiguration, intelligent negotiation, cooperative behavior, and survivability with reduced human intervention. This will be accomplished by creating unique and powerful new abilities for computers to learn about and understand the world, and to reason intelligently with the results of learning. Cognitive systems will typically comprise three primary types of processes: reactive, deliberative and reflective. Each of these will be improved through learning and reasoning. Reactive processes respond quickly and directly to known stimuli. Deliberative processes embody what is usually known as “thinking.” Reflective (higher-order) processes allow a system to “step back” and evaluate the environment and their own capabilities to decide the next appropriate course of action. Capabilities developed in this project include novel representations for knowledge, skill learning, reasoning (deductive, abductive, planning, strategic inference, and hybrid approaches), pattern detection, and language learning, all of which will extend fundamental computing capabilities for dealing with real-world information complexity and uncertainty.

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

|                              | FY 2003 | FY 2004 | FY 2005 |
|------------------------------|---------|---------|---------|
| Integrated Cognitive Systems | 12.198  | 31.046  | 40.146  |

(U) The Integrated Cognitive Systems technology thrust will build upon prior DARPA programs that developed improved human-computer interaction capabilities and highly-responsive computing systems to develop technology for a new class of integrated, highly functional cognitive systems. These systems will act purposefully to assist military commanders and decision-makers. Embedded learning will provide faster response times and more effective responses by retaining what has been learned in the past and applying this knowledge to new scenarios, and most importantly, will allow the performance of a cognitive system to improve over time. The Integrated Cognitive Systems thrust comprises Personalized Assistant that Learns (PAL), Dismounted Soldier Complement Enhancing Reporting and Navigation (DISCERN), and Cognitive Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR).

- The Personalized Assistant that Learns (PAL) program will develop integrated cognitive systems that will act as personalized executive-style assistants to military commanders and decision-makers. It is only through the exploration of full, integrated systems that we can ultimately validate the effectiveness of component technologies developed to support machine reasoning and learning. Initially the program will strive to create assistant programs that will display basic competencies, including interaction with people and other assistant programs in a normal operational environment; sending and receiving information in a natural manner; relating information and activities in various different media; interacting with the assistant's user and inferring preferences and how to do useful procedures; and accepting coaching and guidance expressed naturally in language. Such systems will push the limits of technology for formal reasoning and learning, all integrated in a unified multitasking, mixed-initiative architecture. The program will demonstrate cognitive systems that make use of basic knowledge and past experience to help the system understand and seek input, resulting in systems that do purposeful perception (i.e., sensor information will be acquired, filtered and processed to serve specific, high-level goals). Methods for processing raw data will be learned in a way that optimizes performance of the entire system.
- The Dismounted Soldier Complement Enhancing Reporting and Navigation (DISCERN) program will develop episodic memory mechanisms to augment the individual warfighter's ability to accurately recall and communicate experienced events to reduce the operational impact of the "fog of war." The warfighter's understanding of what is happening depends critically on knowing what has

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already happened. To facilitate situational awareness, the military has developed extensive standardized reporting mechanisms and procedures to support the capture of information and its communication to where it is needed. The warfighter is called upon to recall and report, in a timely and accurate manner, salient events that are experienced. However, the noise, smoke, and confusion of the battlefield, and the physiological and psychological stresses of combat, make this task very difficult. Furthermore, sleep deprivation reduces the warfighter's recall effectiveness even when physically removed from the battlefield. Foundational episodic memory technologies will be developed and applied to support and enhance after-action report generation, information sharing between dismounted squad members, information sharing across multiple shifts of command center staff, and the interaction of trainees and instructors in training situations. Lives depend on the decisions made by warfighters, from the theater commander down to the squad member on patrol. This effort will maximize the sensor and information resources available to the network-centric warfighter to improve not only the individual's cognitive ability but also the effectiveness of the collective force.

- The Cognitive Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) program will develop specific embedded learning and real-time reasoning elements to enable a new generation of C4ISR. The embedded learning will provide faster response times by retaining what it has learned in the past and real-time reasoning allows the system to apply what has been learned to new scenarios. The resulting knowledge will assist the commander by providing critical information in a timely manner with alternative courses of action for more effective decision-making. The Cognitive C4ISR program will provide flexibility and adaptability technologies as part of the solution to time-critical decision-making in the face of increased ambiguity, deception, and surprise within the engagement timeline.

(U) Program Plans:

- Personalized Assistant that Learns.
  - Develop baseline architecture for a complete PAL system.
  - Develop initial knowledge base representing a PAL system's knowledge of its task domain.
  - Demonstrate continuous teaming capability over a protracted period of time.
  - Develop technology for a PAL system to interact with its user and perceive activities over time and develop understanding of 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.



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- Develop core machine learning, knowledge base and flexible planning technologies to enable development of a cognitive planning agent.
- Develop core physical awareness, cyber-awareness, multimodal dialogue, machine learning, and representation and reasoning technologies to support a cognitive assistant for executive functions.
- Develop test problems, define metrics, and conduct formal experiments to evaluate progress in cognitive systems technology R&D.
  
- Dismounted Soldier Complement Enhancing Reporting and Navigation.
  - Abstract input data streams into sequences of events and states, which are aggregated into threads and episodes to produce a timeline that constitutes an "episodic memory."
  - Develop an ontology-based data structure that indexes data for rapid retrieval and continually evolves as the data is processed to generate multiple layers of representation at increasing levels of abstraction through inference and reasoning.
  - Demonstrate the capability to present critical situational awareness elements such as "who", "what", "where", and "when" to the soldier in a hands-free manner, reducing the reporting burden and increasing the recall and reporting content quality.
  - Demonstrate the effective sharing of information in dismounted warfighting, command center, and training environments.
  
- 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 maybe 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.
  - Develop a unified cooperative system to provide a means for integrating dissimilar C4ISR systems.

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|                                  | FY 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Foundational Learning Technology | 2.000   | 9.139   | 14.500  |

(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 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 to adapt in real time to the naturally changing environment without programmer intervention. The application of this technology will result in military systems that are more robust, self-sufficient, and minimize platform-specific customization. The Foundational Learning Technology thrust comprises Real-World Learning, the Neuromorphic Learning Technology and the Learning Locomotion and Navigation programs.

- The Real-World Learning program will explore the integration and application of advanced machine learning techniques to enable cognitive computing systems that learn from experience and adapt to changing situations. The program will determine which types of learning (e.g., learning by example, learning by analogy, statistical learning from training data, explanation-based learning, etc.) are most effective when applied to challenging problems of importance to the military. Moreover, this technology program will drive the design and implementation of new hybrid learning technologies that allow cognitive systems to learn in a wider variety of situations; among other things, these new methods will combine statistical learning techniques with knowledge-based techniques that take into account background knowledge and *a priori* experience. This technology will also enable a new generation of flexible machines capable of pattern recognition and adaptive behavior that respond to dynamic interaction in parallel. Developing technologies that allow enduring systems to learn continuously over long periods of time is a goal of this program.
- The Neuromorphic Learning Technology program will combine principles from computational neuroscience with traditional Artificial Intelligence-based symbol processing and knowledge representation to enable a new class of intelligent systems with generalized neuromorphic learning and self-organizing capabilities. Subsystem development and integration will be based on adaptive, self-organizing models. Such incremental adaptation will allow systems to grow and change with their environments, even to adapt around failed components. System design will be based on a general set of organizing principles, rather than in developing individual rules and

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processes. Unlike rule-based systems, these networks will self-organize into a functional system, developing the rules themselves. These systems will leverage the statistics of large numbers of simple computing elements to enable incremental learning, high-speed parallel evaluation, and fault tolerance.

- An outgrowth of Autonomous Software for Intelligent Control previously funded on Project ST-33, the Learning Locomotion and Navigation program will develop learning and reasoning technologies specifically for robotic systems. These enhanced robotic systems will automatically learn to interpret sensor data and apply this knowledge to the control of their actuators for improved locomotive and navigational autonomy in complex environments with changing terrain and heterogeneous obstacles. Approaches in reinforcement learning and technologies for learning from example will be explored. These learning technologies in locomotion and navigation will open new horizons in unmanned military operations, surveillance and reconnaissance, and will dramatically advance the state of autonomous vehicles, especially for tasks requiring higher-level computation, such as perception-based navigation.
- (U) Program Plans:
- Real-World Learning.
    - Select several critical problems and scenarios to challenge machine learning technology in ways that will determine the essential value of individual techniques.
    - Classify a broad variety of problems into classes that are best addressed by different types of learning technologies and determine the most powerful and comprehensive sets of techniques that complement one another.
    - Design and develop hybrid learning systems that allow cognitive systems to adapt to a wide variety of naturally-occurring situations and perform better over time against challenges similar to those challenges to which they have been exposed in the past.
    - Develop algorithms that generalize based on information gathered and learned to operate successfully in similar, but not identical situations.
  - Neuromorphic Learning Technology.
    - Investigate the role of parallel architectures, algorithms, and general principles inspired by neuroscience in hybrid learning and adaptive systems, rigorously comparing neuromorphic approaches to more traditional AI approaches and others developed under this program.

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- Develop dynamic adaptation technologies for probabilistic action selection to create complex mappings of integrated input data to enable self-organization of necessary data representations.
- Learning Locomotion and Navigation.
  - 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.
  - 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.

|                         | FY 2003 | FY 2004 | FY 2005 |
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| Knowledge-Based Systems | 0.000   | 12.241  | 17.500  |

(U) The Knowledge-Based Systems program, formerly budgeted in Project ST-33, will develop enabling technologies, methodologies, ontologies, and specific 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 program will develop technologies for codifying, linking, integrating, accessing, and using complex and cross-disciplinary knowledge at widely varying scales. This capability at a strategic level will provide DoD decision-makers with rapid as-needed access to decision-relevant background knowledge from a broad spectrum of distributed sources. The knowledge will be expressed in formal knowledge representation languages that will allow computers to reason about the knowledge, consider its implications, imagine possible future scenarios, and query the warfighter for clarification of various aspects of the information. The significant challenges are centered on the fact that critical knowledge involves temporal information, complex belief structures, and uncertainty, and current representation technology is not adequate to capture such information. This program will also develop the 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 replanning. By formalizing situation model representations, automated support will be provided to commanders and analysts for prediction of unforeseen events and determination of the relevance of isolated or partial events to the evolving situation. To achieve these objectives, this program will formalize situation representation and develop analogical and case-based reasoning, functional representation languages and situation markup languages

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technologies. This effort would then provide the warfighter with intelligent automated assistance to help him plan and accomplish his daily activities and, over time, learn how he accomplishes these tasks and provide increasingly valuable automated assistance.

(U) Program Plans:

- Develop knowledge module authoring tools.
- 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.

|                   | FY 2003 | FY 2004 | FY 2005 |
|-------------------|---------|---------|---------|
| Advisable Systems | 0.000   | 8.077   | 12.027  |

(U) The goal of the Advisable Systems program is to design and build systems that warfighters can control in natural and flexible ways – not via menus or by programming them, but by exchanging advice and instructions with them. “Advice” will span a spectrum ranging from high-level policy and goals to intermediate preferences and constraints on system behavior to specific direction and contingency actions. The warfighter will be able to express this advice in natural English and engage in a dialogue to clarify/elaborate the general advice. Based on this dialogue, the system will incorporate the advice into an executable plan and start behaving as if it were originally programmed for that function. As Advisable Systems mature, this behavior will increase in complexity from configuration of existing capabilities to the automated acquisition or generation of new capabilities. Advisable Systems will furthermore continuously engage in natural dialogues with warfighters as they encounter unforeseen circumstances or conflicts in priorities and standing orders, eventually becoming fully autonomous in their functioning as commanded. Although progress in this area will require initial focus on selected mission domains to constrain the dialogue, tools will be developed for adapting the technology to other domains. While natural language interfaces are an essential enabler for Advisable Systems, this project will not support

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speech recognition research *per se* (except where important conceptual gaps exist that would bear on successful expression of advice and explanations), but rather the development of dialogue management systems that allow systems to glean and clarify warfighter intent. Advisable systems will allow commanders and other decision-makers more natural and more productive access to and control over a wide range of software capabilities in a variety of mission-critical areas, including command and control, intelligence and logistics. (This project was previously listed in ST-33).

(U) Program Plans:

- Select two or three key mission domains and compelling scenarios to drive advisable systems research with a series of increasingly difficult challenge problems. Metrics for assessment include “programming” speed and length of dialogue necessary, correctness of resulting system behavior, and performance of the advisable system versus a hand-programmed one.
- Develop domain-specific intermediate languages for expressing guidance/advice with precise operational and declarative semantics and tools for translating these languages into either executable plans or parameterized configurations of existing software modules.
- Develop a dialogue system with domain-specific semantics for eliciting natural language advice from the warfighter. This dialogue system will translate warfighter guidance into the precise intermediate languages described above for both implementation and verification of purpose and intent.
- Develop protocols and tools for applying policy preferences and constraints and mediating conflicts among them.

|                     | FY 2003 | FY 2004 | FY 2005 |
|---------------------|---------|---------|---------|
| Adaptive Networking | 1.000   | 0.000   | 0.000   |

(U) The Adaptive Networking program assessed the feasibility of information and communication networks that possess significant degrees of self-reliance and responsibility for their own behavior and survival. This research effort is focused on the capabilities of self-diagnosis, automatic adaptation to changing and hostile environments, reconfiguration in response to changes in environment, intelligent negotiation for tasks and resources, and robustness under attack. (This program moves to ST-31 in FY04).

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- (U) Program Plans:
  - Identified and characterized the major components of an adaptive/cognitive network and software functionality for large-scale redesign.
  - Initiated a detailed architectural plan to implement adaptive, self-diagnostic and reconfiguration network capabilities.
  
- (U) **Other Program Funding Summary Cost:**
  - Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Communications, Interaction and Cognitive Networks ST-31                     | 24.180  | 34.140  | 32.433   | 36.069  | 59.833  | 58.570                | 50.512  |

(U) **Mission Description:**

(U) The Communications, Interaction and Cognitive Networks project will dramatically improve warfighter and commander effectiveness by developing revolutionary methods for users to interact with and direct cognitive systems (and the physical sensors and effectors they control) and for large-scale collections of cognitive systems to interact with one another in support of user objectives. Specifically, this project will develop technologies to enable systems to detect and assess the user's cognitive state and adapt to optimize understanding and effectiveness of the user; and high-level languages for rapid but precise specification of complex behavior in response to mission demands, such as configuration of sensor networks. 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 affecting the external world. A remarkable and unique aspect of natural perceptual systems is their ability to take an inordinate amount of raw sensor data, such as visual flow and rich auditory input, filter and integrate that data, and almost instantaneously unify the resultant data into meaningful elements. The human brain is able to create from this information perceptual units that parcel the world into objects and discrete entities that are then recognized, remembered, and used in problem solving. Looking closely at these innate perception abilities will yield insights into how to build totally novel computational systems that identify important, low-frequency events in a noisy environment. This kind of approach should lead to dramatic improvements in the abilities of computers to process and analyze huge amounts of data to form a high-level understanding within their environment. This project will significantly advance the military's ability to address information overload in the operational environment.

(U) Robust interaction among cognitive systems, legacy systems, and operators will require incorporation of advanced models and control of the network infrastructure that connects them to ensure adequate provisioning of quality-of-service under dynamic loads to meet mission requirements. These technologies, taken together, will greatly increase operator effectiveness by allowing the operator to focus on high-level mission objectives rather than low-level interactions with the system while at the same time ensuring that he maintains essential understanding of how (and how well) the system is implementing and responding to that high-level direction.



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

|  | FY 2003 | FY 2004 | FY 2005 |
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| Improved Warfighter Information Processing | 16.012  | 19.706  | 12.763  |

(U) The Improved Warfighter Information Processing (IWIP) technology thrust will develop technologies to enhance the warfighter’s and the commander’s information management capacities and improve decision-making performance. This research area seeks to significantly expand the operators’ capabilities in a real-time operational environment by enhancing intellectual performance in the way that weapons, vehicles and sensors extend operators’ physical capabilities today. In addition, this thrust will 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. The hypothesis of this emerging area is that recent impressive 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, advance 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 (Augmented Cognition) program will develop the means, devices, and infrastructure necessary to assess the warfighter’s or commander’s status in real time and then enhance operational effectiveness via adaptive strategies in order to greatly improve the information throughput in the computational interface. This program will develop the technology to integrate new digital devices that support memory, attention, and context recovery and link that support with the operator’s status to directly improve overall performance in complex and operationally stressful conditions. The program will culminate in the development of closed-loop computational systems in which the computer system adapts to the state of the warfighter or decision-maker to significantly improve performance. The program will enhance operational effectiveness through at least these specific improvements to operator efficiency: 1) increasing the amount of information that operators can handle; 2) reducing manpower requirements (e.g., one person doing the job of three); and 3) improving attention management during stressful operations. This 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 deliver content more effectively to the operator. The effort will design and build adaptive

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multimodal interfaces that improve the ability of the warrior to communicate on the battlefield and the commander to operate in a command center, and exploit all of the digital information currently available only in a static command environment.

- The Context-Based Computing for Command and Control (CBC<sup>3</sup>) program will demonstrate dramatic improvements in command decision-making based on the development of “context-based computing” to maintain situational awareness in real time. CBC<sup>3</sup> will also seek to find ways to capture in real time the context (situation assessment including information about places, people, time, functional activities, etc.) that is critical for supporting the decision maker in a meaningful way. The long-term impact of this work will be to provide users with vastly expanded expressive power, interface flexibility and transparency, more timely access to key 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.
  - Design closed-loop computational interfaces to mitigate specific information-processing bottlenecks that serve as roadblocks to high performance and information flow; elaborate interfaces into full-fledged “decision-interactive spaces” to illustrate the full power of decision-focused computing for command and control.
  - Develop intelligent interruption strategies to effectively increase limited working memory capacities in command and control environments.
  - Develop adaptive attention management methods to improve focus during complex operational tasks facing the dismounted soldier.
  - Develop cued memory retrieval strategies to enhance situational awareness and context recovery in information-rich unmanned-vehicle control stations.
  - Develop modality switching strategies (i.e., audio, visual) to adapt information delivery interfaces in mobile command and control settings.
  - Integrate sensor technologies into a suite of warfighter status “gauges” that will permit the assessment and enhancement of warfighter performance for order-of-magnitude improvement in operator efficiency.
  - Demonstrate and evaluate methods for using multimodal query of digital memory to enhance performance; create capabilities for a command center to interpret multimodal input streams; and interpret what is going on within it.

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- 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, testing their performance and usability advantages within multimodal systems developed in the program; these will include protocols for the proactive manipulation and presentation of information.
- Context-Based Computing for Command and Control.
  - Identify decision-making bottlenecks, impediments, and opportunities in the context of on-going military and non-military operations.
  - Identify critical information exchanges between command centers at different echelons and define operational metrics for decision-making.

|                         | FY 2003 | FY 2004 | FY 2005 |
|-------------------------|---------|---------|---------|
| Collaborative Cognition | 0.000   | 3.780   | 8.670   |

(U) The Collaborative Cognition technology thrust will enable the design and implementation of collaborative software agents in dynamic multi-agent environments (which include both software agents and people). The resulting technology will allow software agents to cope with limited and/or noisy sensor information; limited communication capabilities; changing and unforeseen environments and other agents; and limited *a priori* knowledge of each other's capabilities. An outgrowth of previous DARPA work such as Control of Agent-Based Systems (CoABS), the technology can quickly and efficiently explore the application of innovative cognitive and behavior modeling approaches to intelligent software agent systems. The Collaborative Cognition technology thrust comprises Collaborative Cognition Systems and Coordination Decision-Support Assistants.

- 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. In particular, the software will be adept at controlling agent programs under previously unseen or unknown conditions. This work will

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explore revolutionary concepts for applying distributed agent technology, first to modeling and simulation systems, with the long-range goal of applying this technology to operational environments, delivering a leap ahead in the capability of intelligent systems.

- The Coordination Decision-Support Assistants (COORDINATORs) program will develop a new class of cognitive systems that learn and reason about performance in order to provide dynamic activity coordination and decision support to the warfighter. The program seeks to dramatically improve the coordination of warfighter activity in dynamic operational environments including task selection and scheduling. The COORDINATORs program will enhance system performance, improve response times, increase adaptability and flexibility, add a level of reliable autonomy and decrease the number of assets required to perform tasks or solve problems. COORDINATORs, through real-time reasoning that adapts and changes in response to the environment, will enable commanders to focus on the “hard problems” and offload certain mechanizable coordination decision tasks to automated systems as necessary and appropriate.
- (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 and 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.
  - Coordination Decision-Support Assistants.
    - Develop algorithms that allow distributed, real-time coordination and scheduling (avoiding centralized bottlenecks and single points of failure); extend those algorithms to plan courses of action in an adaptive and flexible manner.
    - Develop distributed coordination and autonomous control to coordinate activities.
    - Develop machine learning algorithms to enable the coordination systems to learn concepts of operation and commander preferences for coordination decision-making.

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|                               | FY 2003 | FY 2004 | FY 2005 |
|-------------------------------|---------|---------|---------|
| Self-Aware Collective Systems | 0.000   | 3.336   | 7.000   |

(U) The Self-Aware Collective Systems technology thrust will enable heterogeneous teams of individuals (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. Self-Aware Collective Systems offer a powerful set of concepts intended to empower warfighters to take full advantage of all available information and to bring to bear all available assets in a rapid and flexible manner. The technology will improve information sharing and situational awareness in heterogeneous environments by robustly and dynamically networking teams of agents and warfighters cooperating on a specific task. The Self-Aware Systems thrust is comprised of two programs: Self-Aware Peer-to-Peer Systems and Collective Cognitive Information Processing for Improved Asset Performance.

(U) The Self-Aware 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 support battlespace awareness by enabling the self-formation of large *ad hoc* networks of sensors and computational elements within the severely resource-constrained environment (power, bandwidth, stealth) of military operations while enabling networks to survive component failure, network intrusion, and the subversion of elements. This self-aware network of sensors and communication element 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. Therefore as elements fail or are subverted, the Self-Aware Peer-to-Peer Systems will control the graceful degradation of any of its parts. This technology will support a variety of networks of manned and unmanned systems.

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(U) The Collective Cognitive Information Processing for Improved Asset Performance program will develop learning and reasoning algorithms that can identify and classify emergent problems and opportunities for proactive maintenance of equipment and use of sensors in a dynamic operational environment. In a way that is unachievable from the local perspective of an individual element in the collection, these new self-aware distributed systems will be able to reflect globally on their overall operation (including understanding trends), and make decisions based on the collective disposition of assets connected by sensors (e.g., vehicles or other equipment). One consequence of this new approach would be significantly increased reliability and readiness of military equipment because information from all equipment is seen and correlated globally, rather than just locally on individual vehicles. This technology will enable commanders to optimize the mix of resources required for a particular task, allowing fewer resources to accomplish extended military operations.

(U) Program Plans:

- Self-Aware Peer-to-Peer Systems.
  - Define and develop cognitive representations and distributed agent technologies, information fusion algorithms, diagnostic and prognostic algorithms, network control language, and network benchmarks.
  - Integrate image recognition, adaptive 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-aware, self-forming networks allowing for distributed control; allow the overall collective to 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.
- Collective Cognitive Information Processing for Improved Asset Performance.
  - Identify and classify emergent behavior of equipment performance and utilization in a dynamic operational environment; use historical data collected in an operational setting.
  - Create technology for forming a dynamic knowledge base to hold and process information from a distributed collection of vehicles or other assets.

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- Apply learning through observation, monitoring and data collection, and integrate operator input to augment data sets and modules to provide critical health and status of equipment.
- Develop computational mechanisms for producing recommendations for specific proactive maintenance or sensing actions based on reasoning over information collected on a real-time basis from a distributed set of platforms.

|                      | FY 2003 | FY 2004 | FY 2005 |
|----------------------|---------|---------|---------|
| Cognitive Networking | 0.000   | 1.472   | 4.000   |

(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 systems 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 explore the possibility of a virtual “application-private network”, whose on-demand protocols are based on specific application requirements and current network conditions. It will also attempt to create a “cognitive radio” capability, which uses cognitive information processing to optimize communication based on current conditions, past experience and high-level user guidance.

(U) The Adaptive Networking program will assess the feasibility of information and communication networks that possess significant degrees of self-reliance and responsibility for their own behavior and survival. This research effort will focus on the capabilities of self-diagnosis, automatic adaptation to changing and hostile environments, reconfiguration in response to changes in the environment, intelligent negotiation for tasks and resources and robustness under attack. Key research challenges for the program are the development of formal models and representations that enable collective learning and reasoning in the distributed setting; development of a decentralized, scalable overlay architecture; and accurate responses to the changing issues that arise in complex trust and administrative environments. This program will dramatically increase information assurance through the reduction of human error in network management. These technologies will enable the military to achieve smaller, more agile rapid-deployment forces through self-configuring, self-managing networks. (This project was previously listed in ST-30.)

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- (U) Program Plans:
- Identify and characterize the major components of an adaptive/cognitive network and software functionality for large-scale redesign.
  - Develop a detailed architectural plan to implement adaptive, self-diagnostic and reconfiguration network capabilities.
  - Design and develop a broad collection of specific cognitive network protocols and network management software for automatic statistical diagnosis and control.
  - Design and implement an experimental cognitive physical network infrastructure.

|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Network Modeling and Simulation | 8.168   | 5.846   | 0.000   |

(U) The Network Modeling and Simulation (NMS) program develops software to enable the autonomous prediction, design and control of complex networks over a broad range of time scales, network sizes, composition and performance. New models and simulators will enable reliable and rapid planning, design, analysis and configuration of military and emergency networks with minimal manual intervention.

- (U) Program Plans:
- Develop a hybrid simulator integrating fluid and multi-fractal models. Achieve 100x scalability in network size, 50-100x speed in simulation over sequential techniques, for both wired and wireless networks.
  - Implement measurement and simulation based, on-line prediction of core Internet, and border gateway protocol, stability and vulnerability, including that arising from virus propagation.
  - Develop a simulator suitable for on-line network analysis and control, and scalable to tens of thousands of nodes.
  - Demonstrate on line network controls including quality-of-service provisioning and dynamic reconfiguration.
  - Demonstrate 10 to 100 x improvements in time to field new protocols, fault and vulnerability diagnosis, over operator-intensive current techniques.
  - Transition 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.



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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Computing Foundations ST-32  | 8.282   | 17.583  | 27.552   | 33.450  | 41.283  | 48.094                | 52.892  |

(U) **Mission Description:**

(U) The Computing Foundations (formerly Cognitive Systems Foundations) project will develop novel system-level solutions through the intelligent integration of cognitive agent capabilities built on robust software and hardware infrastructure. To handle increasingly complex jobs, next-generation computer systems will need to integrate the cognitive capabilities of reasoning, learning, explaining, and self-awareness, and be able to be advised and cope robustly with surprise. These aspects of intelligence will be combined in innovative ways with powerful new conventional computing architectures. Overall this element seeks to make fundamental scientific and mathematical improvements in our understanding of and ability to create information and computing systems. The next generation of systems, with cognitive capabilities, may also form teams to achieve goals in a coordinated manner, exceeding the performance of individual systems or humans working alone. Current fragile commercial systems will require enhancements or radical changes to support this revolutionary objective. The new computing foundations will extend beyond today's standard Von Neumann computing model.

(U) 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 their means drives the need for systems that are able to dynamically adapt, collect and assimilate large quantities of data, and remain robust under a large set of potential failure conditions and threats. Computing Foundations will enable next-generation systems to be more responsible for their own monitoring and protection, as well as for restoring themselves to full capability after an attack or failure.

(U) In addition, the plan is to develop, evaluate, prototype and demonstrate a set of promising concepts in the context of full-scale test-beds in realistic scenarios and environments. The next transformational revolution for military force development will be the seamless integration of autonomous physical devices, computation software agents, and humans. Transition goals are military next-generation network-centric systems and platform-specific information collection and processing systems in space, air, sea and land.

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

|                           | FY 2003 | FY 2004 | FY 2005 |
|---------------------------|---------|---------|---------|
| Self-Regenerative Systems | 3.653   | 5.778   | 10.500  |

(U) The Self-Regenerative Systems (SRS) program will conceive, design, develop, implement, demonstrate and validate architectures, tools, and techniques for fielding systems capable of adapting to novel threats, unanticipated workloads and evolving system configurations. Employing innovative techniques like diversity and scalable redundancy as well as higher-level cognitive functions such as reasoning, reflection, and learning, SRS technologies will allow future information systems to be dramatically more robust, survivable, and trustworthy than today’s systems. 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. Also, they will maintain their robustness and trustworthiness attributes even as they undergo growth and evolution in functionality and performance over time.

(U) Program Plans:

- Identify novel attacks and generalize and learn from specific attack events to form a defense against a general set of cyber-attacks and failures.
- Develop technologies to diagnose and assess damage, repair and recover from damage caused by accidental faults, software aging, or malicious activities and, generally, heal the system automatically.
- Develop information systems that can assess dynamic security risks and predictively adapt their security posture to anticipated threat conditions, and adaptively balance performance and functionality with security.
- 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.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Architectures for Cognitive Information Processing | 3.336   | 6.280   | 10.552  |

(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 fundamentals, framework and development environments that will provide the basis for and enable innovative and truly efficient cognitive processing. Current intelligent processing implementations depend on the use of existing numerically-based architectures and/or standard software architectures, and therefore are implemented via algorithms and processing architectures that are potentially ill-suited to cognitive tasks. To realize the impact and promise of cognitive processing, approaches, algorithms, and architectures that are attuned to cognitive processing fundamentals and that efficiently implement unique cognitive structures need to be established. 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 to support efficient implementations. In order to focus and establish context for the ACIP program, ACIP will pursue focused in-context DoD mission areas for the development of ACIP concepts. ACIP will develop implementations that will span the areas of perception, reasoning and representation, learning, and communication and interaction to enable new classes of cognitive information processing applications that move us dramatically forward toward the overall goal of creating computer systems that truly know what they are doing.

(U) Program Plans:

- Establish a Cognitive Information Framework that will provide common cognitive development environments, tools and evaluation methods for cognitive algorithm and architecture developments, providing an enduring cognitive basis for a broad set of domains and applications.
- Establish proof-of-concept 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 also uses deliberation to plan and solve problems.
- Establish and demonstrate a first-generation framework supporting cognitive approach implementation, algorithm development and architectural evaluation.

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

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Security-Aware Systems (formerly Visibly-Controllable Computing) | 1.293   | 5.525   | 6.500   |

(U) Today's mechanistic military software systems are brittle in the face of changing requirements, and vulnerable to skilled attackers who bring creativity and unpredictability to their strategies. Prior work in system security has focused on flexible design and removing, or compensating for vulnerabilities. These approaches, however, cannot be perfectly realized and risk to military systems remains high. The goal of a security-aware system is to minimize unavoidable cyber risk to military missions by having a system itself smoothly adapt to changing resources, building blocks, security requirements, mission goals and threats. A security-aware system will reason about its own security attributes, capabilities and the utility of its functions with respect to a mission context. A security-aware system will dynamically adapt to provide desired levels of service while minimizing risk and providing coherent explanations of the relative safety of service level alternatives.

(U) The Security-Aware Critical Software (SACS) program, formerly Visibly-Controllable Computing, will leverage the research conducted under Cyber Panel and other DARPA programs to create a new generation of software that provides a comprehensive picture of security properties and current status, and will present this information at multiple levels of abstraction and formality. SACS will eliminate confusing and information-free error messages in favor of useful explanations. This capability will make security properties and status transparent to decision-makers, which will increase the speed and confidence with which military systems can be securely and dynamically reconfigured, particularly under stressful conditions. SACS will revolutionize the security of general-purpose information systems and reduce the threat from stealth attacks in which attackers take control of systems without being detected. 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 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.

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- Develop techniques to summarize security policy and status so that the descriptions produced by SACS can be understood while at the same time not omitting critical details.
- Augment current techniques to construct a framework for developing high-assurance behavioral specifications (including security policies). Formulate a unified knowledge base to represent the properties and capabilities of disparate security mechanisms.
- Develop static and dynamic source code analysis techniques (e.g., data- and control-flow-based techniques, model-checking, strong typing) to relate software module structures and runtime state with the representation of security properties/configurations.
- Demonstrate self-explanation techniques in which systems explain their critical security properties and status in a manner that is understandable to a variety of managing software components and human operators.
- Develop testing and validating protection mechanisms of security products to certify protection to quantifiable levels based on a scientific rationale.
- Develop measures of merit and metrics to quantitatively characterize various dimensions of security (availability, integrity, confidentiality, authentication, and non-repudiation), fault tolerance, and intrusion tolerance and show the relevance of the theory by applying it to a realistic exemplar system.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Knowledge Representation and Reasoning ST-33                                 | 26.399  | 3.472   | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |

(U) **Mission Description:**

(U) The Knowledge Representation and Reasoning project is exploring technology central to the creation of a new class of computational systems – Cognitive Computing Systems that will reason, learn, and respond intelligently within the dynamic environment of military operations. The real power of information processing emanates from higher-level capabilities that use abstraction, mental simulation and planning, hypothetical reasoning, powerful language understanding and generation capabilities and self-awareness. This program will develop novel and effective technologies for representing knowledge of the world and accompanying methods of reasoning (including deductive, abductive, planning, strategic, analogical, and hybrid) methods. The Knowledge Representation and Reasoning project comprises Autonomous Software for Intelligent Control, Knowledge-Based Systems and Advisable Systems.

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

|   |         |         |         |
|---|---------|---------|---------|
|   | FY 2003 | FY 2004 | FY 2005 |
| Autonomous Software for Intelligent Control | 16.437  | 3.472   | 0.000   |

(U) The Autonomous Software for Intelligent Control effort will program a variety of autonomous mobile robots to independently perform military tasks in a diverse spectrum of complex, dynamic environments. The goal is to advance real-world performance in the tasks of perception-based autonomous vehicle navigation and effective natural interaction of robots with humans. Representations of tasks, goals, plans, common-sense knowledge, and perceived environmental features, including soldier interaction, are core to this effort. Several alternative approaches are being pursued to augment pre-programmed activities and responses with powerful learning-derived competencies for perception and control analogous to those of natural systems. This software will enable autonomous systems to effectively reason about real-world situations in order to appropriately modify their behaviors. Integrated perception, including fusion of data from multiple sensor and multiple processing modalities of the same data will reduce operator intervention and achieve semi-autonomous operation. The resulting highly capable robots will have the ability



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to learn new tasks and adapt quickly to changing environments (with minimal programming effort) essential for applications in the battlespace of the future.

(U) Program Plans:

- Demonstrate adaptive generation of complex behaviors; multi-sensor-enabled, outdoor navigation; and methods for directing perceptual attention.
- Develop and demonstrate an integrated robust on-road driving system capable of operating in a natural environment with congestion.
- Demonstrate a trainable, perception-based, autonomous navigation capability for robots in urban environments.
- Integrate perceptual, behavioral, and natural interactive capabilities onto a humanoid robotic platform, and measure the relative performance of supervised and autonomous behavior modes.
- Develop distributed perception-based autonomous navigation behaviors for unmanned surface vessels (USVs) and share information between multiple USVs, to achieve cooperative target tracking, interception, and self-defense.
- Demonstrate cognitively compatible teams of semi-autonomous, semi-independent robots, with adjustable interaction modes.
- Develop infrastructure and tools to seamlessly integrate communications, control, and perception capabilities to implement a networked team of air and ground unmanned vehicles for reconnaissance and area patrol.

|                         | FY 2003 | FY 2004 | FY 2005 |
|-------------------------|---------|---------|---------|
| Knowledge-Based Systems | 5.842   | 0.000   | 0.000   |

(U) The Knowledge-Based Systems program will develop enabling technologies, methodologies, ontologies, and specific 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 program will develop technologies for codifying, linking, integrating, accessing, and using complex and cross-disciplinary knowledge at widely varying scales. This capability at a strategic level will provide DoD decision-makers with rapid as-needed access to decision-relevant background knowledge from a broad spectrum of distributed sources. The knowledge will be expressed in formal knowledge representation languages that will allow computers to reason about the knowledge, consider its implications, imagine possible future scenarios, and query with warfighter for clarification of various aspects of the

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information. The significant challenges are centered on the fact that critical knowledge involves temporal information, complex belief structures, and uncertainty, and current representation technology is not adequate to capture such information. This program will also develop the 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 replanning. By formalizing situation model representations, automated support will be provided to commanders and analysts for prediction of unforeseen events and determination of the relevance of isolated or partial events to the evolving situation. To achieve these objectives, this program will formalize situation representation and develop analogical and case-based reasoning, functional representation languages and situation markup languages technologies. This effort would then provide the warfighter with intelligent automated assistance to help him plan and accomplish his daily activities and, over time, learn how he accomplishes these tasks and provide increasingly valuable automated assistance. (This program moves to project ST-30 in FY04).

(U) Program Plans:

- Identify methods and protocols for using interoperable knowledge modules resident on distributed knowledge servers.
- Explore integrated knowledge representation and learning technology that enables effective representation of essential forms of knowledge.
- Initiate development of knowledge module authoring tools.

|                   | FY 2003 | FY 2004 | FY 2005 |
|-------------------|---------|---------|---------|
| Advisable Systems | 4.120   | 0.000   | 0.000   |

(U) The goal of the Advisable Systems program is to design and build systems that warfighters can control in natural and flexible ways – not via menus or by programming them, but by exchanging advice and instructions with them. “Advice” will span a spectrum ranging from high-level policy and goals to intermediate preferences and constraints on system behavior to specific direction and contingency actions. The warfighter will be able to express this advice in natural English and engage in a dialogue to clarify/elaborate the general advice. Based on this dialogue, the system will incorporate the advice into an executable plan and start behaving as if it were originally programmed for that function. As Advisable Systems mature, this behavior will increase in complexity from configuration of existing capabilities to the automated acquisition or generation of new capabilities. Advisable Systems will furthermore continuously engage in natural dialogues with warfighters as they encounter unforeseen

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circumstances or conflicts in priorities and standing orders, eventually becoming fully autonomous in their functioning as commanded. Although progress in this area will require initial focus on selected mission domains to constrain the dialogue, tools will be developed for adapting the technology to other domains. While natural language interfaces are an essential enabler for Advisable Systems, this project will not support speech recognition research *per se* (except where important conceptual gaps exist that would bear on successful expression of advice and explanations), but rather the development of dialogue management systems that allow systems to glean and clarify warfighter intent. Advisable systems will allow commanders and other decision-makers more natural and more productive access to and control over a wide range of software capabilities in a variety of mission-critical areas, including command and control, intelligence and logistics. (This program moves to project ST-30 in FY04).

(U) Program Plans:

- Select two or three key mission domains and compelling scenarios to drive advisable systems research with a series of increasingly difficult challenge problems. Metrics for assessment include “programming” speed and length of dialogue necessary, correctness of resulting system behavior, and performance of the advisable system versus a hand-programmed one.
- Explore domain-specific intermediate languages for expressing guidance/advice with precise operational and declarative semantics and tools for translating these languages into either executable plans or parameterized configurations of existing software modules.
- Begin development of a dialogue system with domain-specific semantics for eliciting natural language advice from the warfighter. This dialogue system will translate warfighter guidance into the precise intermediate languages described above for both implementation and verification of purpose and intent.

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

- Not Applicable.

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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA2 Applied Research |         |        | R-1 ITEM NOMENCLATURE<br>Embedded Software and Pervasive Computing<br>PE 0602302E, R-1 #13 |         |         |                       |         |
| COST (In Millions)   | FY 2003 | FY2004 | FY2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost  | 54.870  | 13.250 | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |
| Networked Embedded Systems Design AE-01                                      | 19.211  | 5.814  | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |
| Software for Autonomous Systems AE-02  | 21.775  | 7.436  | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |
| Software for Embedded Systems AE-03  | 13.884  | 0.000  | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |

**(U) Mission Description:**

(U) Embedded computing provides the connection between the physical world and computational realm. Embedded computing impacts the superiority of a multitude of DoD systems from avionics to smart weapons. Virtually all new weapon systems from the F-22 aircraft to National Missile Defense and from the Future Combat System to Unmanned Combat Air Vehicles depend on embedded software technology. The level of software complexity in these systems is unparalleled. The goal of the Embedded Software and Pervasive Computing program is to greatly extend the reach and effectiveness of computation from mainframes and desktops into the physical world. These embedded programs pursue the software and systems research to facilitate a new emerging application of computers, and conduct research to greatly increase the autonomy of those systems, to promote the human role from that of operator to supervisor, thereby reducing the mission demand for intensive manpower. Embedded system advancements may revolutionize system and software technology to facilitate the efficacy of the integrated battlefield. This program element will draw to a close at the end of FY 2004. Many of these efforts in Embedded Systems have been funded in PE0602702E, project TT-13, to reorient the research towards specific applications.

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

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behalf of embedded clients. Research on embedded software creation must radically extend the technology to enable the modular composition of software systems subject to physical constraints.

(U) The Software for Autonomous Systems project develops revolutionary control technology to enable predictable, safe, and cooperative operation of free ranging, autonomous systems. DoD needs revolutionary new capabilities for increasing autonomy of weapon systems. Increased autonomy will enable combined manned and unmanned warfare, and the extensive use of robotics technologies empowers future war fighters to accomplish their missions more effectively, reducing the risk of casualties, thereby preserving the U.S. military’s most important resource—the warfighter. The project builds on major advancements in computing and software achieved during the past decade, which make the practical application of complex nonlinear, hierarchical control techniques feasible.

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

| <b>(U) <u>Program Change Summary:</u> (In Millions)</b> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|---|-----------------------|-----------------------|----------------------|
| Previous President’s Budget                             | 58.599                | 13.318                | 0.000                |
| Current President’s Budget                              | 54.870                | 13.250                | 0.000                |
| Total Adjustments                                       | -3.729                | -0.068                | 0.000                |

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|                                  |        |        |
|----------------------------------|--------|--------|
| Congressional program reductions | 0.000  | -0.141 |
| Congressional increases          | 0.000  | 0.000  |
| Reprogrammings                   | -1.729 | 0.073  |
| SBIR/STTR transfer               | -2.000 | 0.000  |

**(U) Change Summary Explanation:**

FY 2003                      Decrease reflects SBIR transfer and minor repricing.  
 FY 2004                      Decrease reflects congressional undistributed reductions and a below threshold reprogramming.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Networked Embedded Systems Design<br>AE-01                                   | 19.211  | 5.814   | 0.000   | 0.000   | 0.000   | 0.000                 | 0.000   |

(U) **Mission Description:**

(U) This project extends DoD's ability to build complex embedded software systems, which are a major source of superiority in modern weapons platforms. Embedded software monitors and controls the physical environment, and lends intelligent behavior to platforms. The design and implementation of embedded software systems require an in-depth approach to information systems. Embedded systems will manage the vast quantities of information that can be accessed by physical sensors, and provided to physical actuators, in direct contact with the real world. To enable the design of these tightly integrated physical and information systems, tools to develop software for them must be extended to accommodate a wide diversity of physical world devices and environments with increasingly ambitious performance goals. Designs must support vast increases in the numbers of processors with real-time data requirements. This work radically extends software development technology to enable the modular composition of software systems subject to tight physical constraints.

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

|   |         |         |         |
|---|---------|---------|---------|
|   | FY 2003 | FY 2004 | FY 2005 |
| Model Based Integration of Embedded Systems | 14.811  | 5.814   | 0.000   |

(U) The Model-Based Integration of Embedded Systems (MoBIES) program is building tools to design and test complex computer-based systems such as avionics, weapons, and communications systems. It simplifies the design of complex embedded systems by focusing on the pre-production environment rather than after-the-fact integration. The approach is to customize the design tools used by applications engineers so that controller design and systems integration can be more fully automated and the errors thereby reduced. The technology will formalize system modeling and programming tools in a common mathematical form. This analysis will allow integrated design of hardware and software from the earliest stages in system development, leading to interoperable tools, automatic systems integration, and simplified test and evaluation. The MoBIES program allows such custom-designed toolsets to be easily tailored to specific applications, resulting in more efficient, verifiable,



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scalable, and re-usable programs for complex weapon and vehicle systems applications. Its objectives are to increase by 100 percent the size of the embedded software programs that existing tools can reliably produce, and decrease by 80 percent the design time necessary to create application-specific tools.

(U) Program Plans:

- Develop methods to integrate different models of computational processes for different applications into a programmable design tool.
- Demonstrate the ability to propagate different physical constraints among design tools.
- Develop hybrid (continuous and discrete) modeling and analysis techniques for embedded systems.
- Develop and demonstrate techniques for the mathematical modeling and formal verification of model-based software generators.
- Demonstrate end-to-end tool integration in avionics, software radio, and vehicle electronics experimental platforms.
- Develop tools for automatically checking safety and reliability properties of automatically generated software.
- Demonstrate the rapid synthesis of embedded systems using customizable frameworks and model-based code generators.
- Develop techniques for integrating different commercial off-the-shelf analysis tools into a single tool environment.
- Develop and demonstrate the use of multiple-view modeling techniques for military avionics, software radio, and combat vehicular electronics applications.

|                                       | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------------|---------|---------|---------|
| Adaptive Reflexive Middleware Systems | 4.400   | 0.000   | 0.000   |

(U) The Adaptive and Reflective Middleware Systems (ARMS) program has focused on the Total Ship Computing Environment (TSCE) for the DD(X) Future Surface Combatant Family of Ships. The TSCE will be a fully integrated open system computing and information architecture that executes all tasks and mission applications optimized at the platform level, rather than the sub-system level, thus breaking down the traditional C4ISR, Combat Systems, and Ship Control System boundaries. The TSCE is a mission-critical distributed embedded system where 1) different levels of service are possible and desirable under different conditions and costs and 2) the levels of service in one dimension must be coordinated with and/or traded off against the levels of service in other dimensions to achieve the intended overall result, even in the face of battle damage or heavy workloads. The autonomous behavior of TSCE systems requires the middleware components and frameworks to adapt robustly to

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quantifiable changes in environmental conditions. In ARMS, middleware is responsible for coordinating the exchange of information efficiently, predictably, scalably, dependably and securely between remote entities by using advanced Quality of Service (QoS) capabilities of the underlying network and end systems. This program moved to PE 0602702E, Project TT-13 beginning in FY 2004.

(U) **Program Plans:**

- Develop adaptive protocols, algorithms, patterns, and tools that enforce security policies to enhance and support secure global resource allocation, scheduling, and control.
- Ensure stability and dependability across multi-level feedback loops in the network-centric TSCE.
- Develop meta-programming policies and mechanisms (instead of application-specific point solutions) to customize QoS -enabled middleware services and applications.
- Develop design expertise (pattern languages) to formalize the successful techniques and constraints associated with developing, generating, and validating QoS-enabled middleware frameworks and protocol/service components.
- Develop reflective techniques for synthesizing optimized real-time and embedded middleware.
- Develop languages, algorithms, and tools to configure customizable—yet standards-compliant—TSCE middleware and applications.
- Demonstrate sufficiently mature technologies that can transition, with moderate to low risk, to the DD(X) Surface Combatant Family of Ships and other DoD combat systems.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Software for Autonomous Systems, AE-02                                       | 21.775  | 7.436   | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |

(U) **Mission Description:**

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

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

|   |         |         |         |
|---|---------|---------|---------|
|   | FY 2003 | FY 2004 | FY 2005 |
| Common Software for Autonomous Robotics | 4.501   | 0.000   | 0.000   |

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

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(U) Program Accomplishments:

- Demonstrated energy-saving protocols with at least 70 percent savings over conventional protocol implementations.
- Integrated developmental network protocols into selected distributed robotic platforms and investigated cooperative approaches to achieve critical situational awareness in the indoor application domain.
- Demonstrated realistic mission scenarios using representative distributed robot platforms in a simulated mission context and in field experiments.
- Developed coordination techniques to support accelerated mobility and reconnaissance for cooperating platforms and developed shared representations to support collaborative communication between humans and robotic systems.
- Developed minimal-resource behavioral algorithms and simulation tools to implement highly scalable distributed approaches to simultaneous localization and mapping, communications, and threat detection.

|                          | FY 2003 | FY 2004 | FY 2005 |
|--------------------------|---------|---------|---------|
| Software Enabled Control | 17.274  | 7.436   | 0.000   |

(U) The Software Enabled Control program is improving the capabilities of control systems for advanced unmanned and manned aircraft. These control systems enhance the autonomy and reliability of both fixed- and rotary-winged unmanned aerial vehicles, and improve the performance of manned vehicles. The challenges are to mathematically model complex changes in flight conditions and vehicle status, to design fast digital control systems to automate maneuvers, and to automatically detect and recover from faults or damage. These techniques will be implemented on a common, open computing platform using a flexible programmer's interface that facilitates reuse of real-time controllers across multiple vehicles. Advanced control system development will exploit recent successes in hybrid systems research, which combine continuous-time systems with randomly occurring discrete events. Hybrid systems can then adapt to sudden changes such as aerodynamic disturbances, threat conditions, damage or failure, or limits in the flight envelope. The software to implement these controls must manage these events and guarantee stable operation throughout the execution of the mission.

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- (U) Program Plans:
- Develop Open Control Platform (OCP) computing services for advanced control of fixed-wing and rotary-wing air vehicles (e.g., flight mode switching, random event handling, stability and optimization, and reliability).
  - Develop and implement a system for high-confidence authority management for vehicle control and mission-management levels.
  - Develop theoretical frameworks for robust hybrid control.
  - Develop software customization, failure reconfiguration, and sensor and actuator resource services for unmanned aerial platforms; integrate with OCP.
  - Integrate coordinated hybrid system services into OCP middleware, facilitating multi-vehicle coordinated control.
  - Develop guaranteed-safe maneuver libraries and control algorithms for coordinated flight.
  - Demonstrate integrated controller with active dynamic models for on-line estimation of external influences such as wind fields and carrier deck motion.
  - Implement and verify adaptive real-time control algorithms on model vehicles and in hardware-in-the-loop simulation.
  - Demonstrate mission-management and dynamic replanning for multiple aircraft using an F-15 and a T-33 UCAV surrogate in coordinated flight.
  - Demonstrate low-level autonomous adaptive flight control using rotary-wing UAVs in complex terrains.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY2004  | FY2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost  | 157.861 | 149.105 | 147.533   | 147.975 | 146.604 | 144.888               | 125.745 |
| Biological Warfare Defense Program BW-01                                     | 157.861 | 149.105 | 147.533   | 147.975 | 146.604 | 144.888               | 125.745 |

(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. Program development strategies include collaborations with pharmaceutical, biotechnology, government, and academic centers of excellence.

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

|                             |         |         |         |
|-----------------------------|---------|---------|---------|
|                             | FY 2003 | FY 2004 | FY 2005 |
| Unconventional Therapeutics | 46.578  | 41.596  | 37.533  |

(U) This thrust is designed to take unique and unconventional approaches for developing therapeutics for a wide variety of threat pathogens that might be encountered in a biological warfare attack. Countermeasures (e.g., Anti-Virals/Immunizations, Anti-Bacterial/Anti-Toxins and Multi-Purpose) under development include: (1) multi-agent therapeutics against known, specific agents and (2) therapeutics against virulence pathways shared by broad classes of pathogens. Specific approaches include developing a new class of antibiotics targeted towards enzymes



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essential to bacterial pathogen survival, identification of virulence mechanisms shared by pathogens, development of therapeutics targeting these mechanisms, efficacy testing in cell cultures and animals, and advanced non-toxic decontamination strategies, including decontamination from radiological poisoning. The development of an artificial immune system through 3-dimensional tissue engineering will provide rapid, in vitro assessments of novel countermeasures against unique DoD threat agents.

(U) Program Plans:

- Transition three (3) small molecule antibiotic technologies to the United States Army Medical Research Materiel Command (USAMRMC) for continued development.
- Transition two (2) BioWarfare and clinical decontamination technologies to advanced development and commercialization.
- Transition multivalent Dengue DNA vaccine to USAMRMC-Infectious Disease for advanced testing and clinical development.
- Transition novel target discovery platform for late stage anthrax therapeutics to United States Army Research Institution of Infectious Diseases (USAMRIID).
- Transition Botulinum Toxin and Superantigen toxin therapeutics to USAMRMC for advanced testing.
- Transition novel modified red cell scavenging technology to USAMRMC.
- Transition technology for good manufacturing practices (GMP) production of vaccines and antibodies in plants as an alternative to traditional manufacturing procedures.
- Develop and mature technology to treat or prevent infections caused by biological warfare pathogens; discover new targets that would protect against engineered organisms.
- Identify new approaches that will significantly shorten the drug development process and increase the efficiency in identifying lead compounds, using in silico modeling and bioinorganic approaches.
- Discover broad-spectrum therapeutics that attack fundamental and common biochemical processes in bacteria and/or viruses.
- Establish a common test-bed for efficacy, safety and drug metabolism in FDA validated models.
- Develop regulators of critical enzyme systems that prevent viral and/or bacterial replication.
- Develop antibody surrogates against agents of interest.
- Explore mechanisms that induce innate immunity and early protection.
- Explore mechanisms of cellular control that are used by pathogens to mask identification.
- Explore the role of plasmid, phage and virus in controlling adaptive mechanisms in bacteria that result in pathogenic phenotypes.

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- Assess the feasibility of accurately identifying "drug-able protein targets" from the known primary DNA structure-using novel computing approaches.
- Rapidly identify novel vaccine targets for bacteria or viruses.
- Develop a rapid response capability for developing candidate DNA vaccines from newly discovered or engineered pathogens.
- Develop new strategies/treatments for late stage biological warfare (BW) infections.
- Demonstrate the inherited and environmentally determined risk to BW pathogen infections as a tool in developing unique treatments.
- Develop a data analysis approach to efficiently identify DNA sequences for gene-chip diagnosis of viral and bacterial infections.
- 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.
- Develop new data analysis capability to interpret biosignature data in individuals incubating a disease.
- Develop an integrated in vitro human immune system, capable of supporting rapid and cost effective vaccine development and testing through the establishment of tools necessary for in vitro fabrication of three dimensional tissue constructs, bioscaffolds and bioreactors.

|                                      | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| Acceleration of Anthrax Therapeutics | 26.000  | 4.000   | 0.000   |

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

(U) Program Plans:

- Validate an alternative primate model to replace the current Rhesus monkey model for testing inhalation anthrax therapeutics.
- Establish preclinical primate drug safety and metabolism capability for testing of candidate drugs.
- Demonstrate preclinical efficacy of anthrax antibiotic candidates.
- Demonstrate preclinical efficacy of immunomodulator drugs against inhalation anthrax.
- Demonstrate preclinical efficacy of late stage anthrax therapeutic candidates.

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| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA2 Applied Research |  | <b>R-1 ITEM NOMENCLATURE</b><br>Biological Warfare Defense<br>PE 0602383E, R-1 #14 |  |

- Demonstrate preclinical efficacy of a novel adjuvant for currently approved anthrax vaccine (improve safety and speed of vaccination).

|                     | FY 2003 | FY 2004 | FY 2005 |
|---------------------|---------|---------|---------|
| External Protection | 5.500   | 6.000   | 10.000  |

(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, new approaches for air filtration and purification, and the detection and cleaning of surfaces contaminated by an attack.

(U) Program Plans:

- Develop, test and transition to the Services a water purification pen capable of disinfecting 300 liters of non-brackish water and a desalination hand pump able to provide 1 liter of sweet water from brackish or seawater in 5 minutes.
- Develop and test a micro fibrous gas adsorbent material with 10-times the gas life and one-half the pressure drop of the current C2A1 gas mask canister.
- Design, develop, test and transition to the Services regenerable air filtration and purification systems suitable for extended personal and collective warfighter and citizen protection.
- Develop new approaches for self-decontaminating surfaces.
- Design, develop and demonstrate systems to detect contaminated surfaces down to the human toxicity levels, and to remove the contamination to below those levels.

|                      | FY 2003 | FY 2004 | FY 2005 |
|----------------------|---------|---------|---------|
| Advanced Diagnostics | 5.000   | 7.730   | 12.000  |

(U) In the early stages, many illnesses caused by biological warfare (BW) agents have flu-like symptoms and are indistinguishable from non-BW related diseases. Early diagnosis is key to providing effective therapy. The advanced diagnostics efforts will develop the capability to detect

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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.

- (U) Program Plans:
- Evaluate hyperspectral strategies for early clinical diagnosis of infection and other medical issues that affect soldier performance.
  - Validate and demonstrate strategies for rapidly generating new probe panels for relevant sample types (in breath, blood and other biological samples).
  - Evaluate and demonstrate multiplexed pathogen detection in microliter samples.
  - Validate and demonstrate strategies for rapid detection of pathogens based on biomarkers for early indication of infection or exposure.
  - 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 2003 | FY 2004 | FY 2005 |
|---------|---------|---------|---------|
| Sensors | 37.654  | 42.000  | 48.000  |

- (U) Organic Based Sensors.
- A unique approach for sensors is the use of cellular, tissue, and organism-based sensors for the rapid detection of biological threats. These cellular and tissue-based sensors have the ability to respond to both known and unknown threats, determine live versus inactivated threat status, and report functional consequences of exposure (mechanisms of action).
- (U) Program Plans:
- Define limits of detection, false alarm rates, and system variability for cell based amplification and detection of biological threat agents.

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- Design and develop sample preparation, processing and delivery methods to maximize bioavailability and activity of the sample and minimize the effect of interferents and fluidics.
- Develop a multitude of critical physiological-based assays that provide information on cellular and tissue responses to a wide variety of threat agents of interest to the Department of Defense.
- Confront the statistical and computational challenges associated with the collection of extremely large datasets from biological sources to include developing software algorithms, models, and other bioinformatic tools aimed at determining acceptable parameters of performance and understanding response profiles.
- Demonstrate the utility of prototype cell and tissue based biosensors in operationally relevant scenarios, including environmental monitoring and medical diagnostics.
- Demonstrate advantages and utility of novel materials developed from mimicking natural biological materials and systems.

(U) Time-of-Flight Mass Spectrometer (MALDI).

- DARPA is developing a small time-of-flight mass spectrometer using Matrix Assisted Laser Desorption/Ionization (MALDI). This approach will enable fluid-free analysis of whole proteins, and therefore make possible fast, reliable biosensors with low false alarm rates and greatly reduced logistics tails.

(U) Program Plans:

- Design and build MALDI time-of-flight (TOF) brassboard system.
- Develop biological warfare agent signature libraries and measure clutter characteristics for MALDI TOF brassboard system.
- Design, build, and test optimized MALDI TOF prototype.
- Develop and validate end-to-end MALDI TOF performance model.

(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

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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.

- (U) Program Plans:
  - Develop isothermal assays for DNA, RNA and protein toxins and demonstrate a false-alarm rate equivalent to the current laboratory technology.
  - Develop a microfluidics testbed for assay optimization and system integration.
  - 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. The sensor is called Triangulation Identification for Genetic Evaluation of Biological Risks (TIGER). It will enable a universal sensor for all pathogens that also holds the promise of detecting the presence of never-before-seen (bio-engineered) agents.
  
- (U) Program Plans:
  - Design and build “gold standard” laboratory instruments for high volume data collection of agent and background signatures.
  - Develop and validate end-to-end performance model.
  - Carry out proof-of-concept analysis, and preliminary performance prediction in clutter.
  - Design, build and test fieldable prototype(s) optimized for environmental and/or diagnostics applications.
  - Characterize prototype behavior in operational environments.

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(U) Spectral Sensing of Bio-Aerosols (SSBA) (formerly Electromagnetic Energy).

- 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. DARPA is investing in this approach, beginning with cross-spectrum data collection and performance models, followed by prototype sensor development.

(U) Program Plans:

- Develop bioaerosol testbed and standardized data-collection protocols.
- 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.).
- Downselect to most promising concepts; design, build, and test prototype sensor.
- Characterize prototype behavior in operational environments.

|                  | FY 2003 | FY 2004 | FY 2005 |
|------------------|---------|---------|---------|
| Immune Buildings | 29.329  | 29.329  | 21.000  |

(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. The program has three goals: to protect the human inhabitants from the effects of the agents; to restore the building to function quickly after the attack; and to preserve forensic evidence for treatment of victims, if necessary, and for attribution. The DARPA focus is on the challenging problem of protection from internal releases of agent, where active and timely control of airflow is required to prevent a building's HVAC system from spreading the agent throughout the

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building. To enable such building-protection systems, DARPA is developing component technologies such as optimized filtration systems, advanced neutralization techniques, 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. 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 buildings.

(U) Program Plans:

- Develop high-payoff component technologies in the areas of filtration, neutralization, and decontamination; and mature sensors as necessary for this active Defense application.
- Demonstrate performance of component technologies in full-scale application.
- Optimize active protection system concepts, and demonstrate performance.
- Characterize the selected demonstration site facility, and design, build, and test an active protection system optimized for that site.
- Integrate existing models, and develop new models as required, into a software toolkit that enables performance predictions for protective architectures in other buildings.
- Validate toolkit predictions in test beds, at demonstration site, and elsewhere as required.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Chem Bio Defense (CBD) Portal Security | 0.000   | 0.000   | 3.000   |

(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, or as an item hand-carried by a visitor.



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- (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).
  - Select the most promising approaches, and use laboratory instrumentation to evaluate collateral damage and false alarms. Develop performance model, and carry out system trades.
  - Design, build, and test optimized prototype system(s).
  - Demonstrate prototype in operational environment, and characterize performance.

|                            | FY 2003 | FY 2004 | FY 2005 |
|----------------------------|---------|---------|---------|
| Wide-Area BWA Surveillance | 1.000   | 1.000   | 0.000   |

(U) The Wide-Area Biological Warfare Agent (BWA) Surveillance program is investigating effective and efficient BWA surveillance systems for urban environments, such as military bases and transportation centers, to detect a covert aerosol release of a BWA and to determine the approximate release location *before the onset of symptoms in humans*. The program is studying 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 are being 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 provide the basis for the Threat Agent Cloud Tactical Intercept and Countermeasure (TACTIC) program.

- (U) Program Plans:
- Conduct trade studies of various potential detection architectures in selected urbanized areas; estimate system performance.
  - Develop analytic methods to geo-locate source based on detector output, meteorology, etc.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Threat Agent Cloud Tactical Intercept Countermeasure (TACTIC) | 0.000   | 0.000   | 7.000   |

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

(U) Program Plans:

- Investigate potential 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.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Mission-Adaptable Chemical Sensors (MACS) | 0.000   | 4.000   | 9.000   |

(U) At present, Nuclear, Biological, and Chemical (NBC) sensors lack a combination of sensitivity (parts-per-trillion) and selectivity (definite identification of molecular species), shortfalls that yield false alarms or worse, failure to detect at all. This effort (formerly named Mother of All

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Sensor Systems) will develop a sensor, based upon rotational spectroscopy of gases, which will eliminate both problems and will achieve the highest possible sensitivity for unambiguous detection of most chemical species. The program will focus on technology for reduction of size and simplicity of function, for equipment that presently is large and complicated, to achieve portability and simultaneous detection of multiple species. It will solve the presently intractable difficulties of remotely identifying chemical threats, in seconds.

- (U) Program Plans:
- 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.

|                           | FY 2003 | FY 2004 | FY 2005 |
|---------------------------|---------|---------|---------|
| Center for Water Security | 1.000   | 1.000   | 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.
  - Continue 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.

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|                               | FY 2003 | FY 2004 | FY 2005 |
|-------------------------------|---------|---------|---------|
| Asymmetrical Products for BWD | 2.000   | 2.000   | 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 stimulate mucosal immunity.
  - Identify likely cytokine molecules and their combinations that result in resistance to pathogens.

|                       | FY 2003 | FY 2004 | FY 2005 |
|-----------------------|---------|---------|---------|
| Desalination Research | 2.300   | 2.550   | 0.000   |

- (U) Program Plans:
- Continue to develop 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, enabling the formation of gas-hydrate-purified, near-potable water ready for final polish by reduced-cost reverse osmosis processes.

|                                   | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Bioscience Center for Informatics | 1.500   | 0.000   | 0.000   |

- (U) Program Accomplishments:
- Conducted research directed at the modeling of disease propagation, rapid detection, and the prediction of risks associated with defense against bioterrorism, building upon such capabilities as distributed databases, geographic information systems, bioinformatics, high performance computing, and modeling.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Center for Tropical Disease Research and Training | 0.000   | 2.000   | 0.000   |

- (U) Program Plans:
- 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 2003 | FY 2004 | FY 2005 |
|-----------------------------|---------|---------|---------|
| EluSys Heteropolymer System | 0.000   | 1.500   | 0.000   |

- (U) Program Plans:
- Explore 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 2003 | FY 2004 | FY 2005 |
|-------------------------------------|---------|---------|---------|
| HPGe Gamma Ray Detection Technology | 0.000   | 1.000   | 0.000   |

- (U) Program Plans:
- Develop new technology for gamma ray detection.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Hand Held Biosensors for Field Detection of Multiple Bioagents CMIM Palm Pilots | 0.000   | 3.400   | 0.000   |

- (U) Explore use of hand held biosensors for detection of bioagents.

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| <b>(U) <u>Program Change Summary:</u> (In Millions)</b> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|---|-----------------------|-----------------------|----------------------|
| Previous President's Budget                             | 161.956               | 137.254               | 138.533              |
| Current Budget  | 157.861               | 149.105               | 147.533              |
| Total Adjustments                                       | -4.095                | 11.851                | 9.000                |
| <br>  |                       |                       |                      |
| Congressional program reductions                        | 0.000                 | -1.599                |                      |
| Congressional increases                                 | 0.000                 | 13.450                |                      |
| Reprogrammings  | 0.000                 | 0.000                 |                      |
| SBIR/STTR transfer                                      | -4.095                | 0.000                 |                      |

**(U) Change Summary Explanation:**

FY 2003      Decrease reflects SBIR reprogramming.  
 FY 2004      Increase reflects congressional adds for seven biological warfare projects offset by undistributed reductions.  
 FY 2005      Increase reflects additional funds for programs in Portal Security and Active Countermeasures against chem/bio threats and a new sensor effort.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY2004  | FY2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost  | 168.826 | 247.405 | 339.175  | 354.525 | 351.751 | 368.253               | 370.404 |
| Naval Warfare Technology TT-03   | 28.746  | 47.613  | 46.813   | 24.971  | 24.656  | 30.643                | 30.628  |
| Advanced Land Systems Technology TT-04                                       | 34.910  | 40.028  | 69.397   | 97.979  | 97.311  | 100.463               | 88.246  |
| Advanced Tactical Technology TT-06   | 64.030  | 90.703  | 112.287  | 116.767 | 119.141 | 133.673               | 133.530 |
| Aeronautics Technology TT-07   | 21.739  | 16.229  | 41.760   | 46.377  | 39.314  | 29.285                | 29.256  |
| Advanced Logistics Technology TT-10  | 19.401  | 19.662  | 15.000   | 0.000   | 0.000   | 0.000                 | 0.000   |
| Network Centric Enabling Technology TT-13                                    | 0.000   | 33.170  | 53.918   | 68.431  | 71.329  | 74.189                | 88.744  |

**(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, Logistics and Network Centric Enabling technologies.

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

(U) The Advanced Land Systems Technology project is developing technologies for enhancing the U.S. military's effectiveness and survivability in operations ranging from force-on-force conflict to military Operations-Other-Than-War. 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 bodies inside of buildings and technology capable of stand-off detection of explosive compounds. The Simulated Isomer Energy Release program will develop techniques to extract and control the



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potent energies stored in nuclear isomers. The Dynamic Optical Tags program will develop new tagging, tracking and location capabilities for U.S. forces. Lastly, the Guided Projectiles program will develop highly maneuverable gun-launched projectiles for defense against ground and air threats.

(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; high speed aerospace vehicle and enabling technology; 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; and small-scale propulsion system concepts. New areas to be investigated are reusable hypersonic vehicles novel helicopter blade designs that reduce acoustic signature and small, low cost high endurance UAV's capable of destroying most enemy UAV's.

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

(U) The Network Centric Enabling Technology project will build sensor, signal processing, detection, tracking and target identification technology 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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|            |  |                       |                       |                      |
|------------|--|-----------------------|-----------------------|----------------------|
| <b>(U)</b> | <b><u>Program Change Summary:</u></b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|            | Previous President's Budget                                | 169.641               | 250.558               | 256.175              |
|            | Current President's Budget                                 | 168.826               | 247.405               | 339.175              |
|            | Total Adjustments  | -0.815                | -3.153                | 83.000               |
|            | Congressional program reductions                           | 0.000                 | -10.153               |                      |
|            | Congressional increases                                    | 0.000                 | 7.000                 |                      |
|            | Reprogrammings   | 0.000                 | 0.000                 |                      |
|            | SBIR/STTR transfer   | -0.815                | 0.000                 |                      |

**(U)** **Change Summary Explanation:**

|         |   |
|---------|---|
| FY 2003 | Decrease reflects SBIR transfer.  |
| FY 2004 | Decrease reflects congressional program reductions for Roboscout, Odortype Detection and undistributed reductions offset by an add to continue funding for the Center of Excellence for Research in Ocean Sciences.   |
| FY 2005 | Increase reflects additional funding in the following projects: TT-03 for the Friction Drag Reduction program; TT-04 for additional programs for anti-sniper efforts, compact military engines and urban sensors; TT-06 for new advanced mathematics/algorithm development, laser techniques and advanced training systems; and TT-07 for Reusable Hypersonics. |

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Naval Warfare Technology TT-03   | 28.746  | 47.613  | 46.813   | 24.971  | 24.656  | 30.643                | 30.628  |

(U) **Mission Description:**

(U) The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. Enabling technologies include concepts for expanding the envelope of operational naval capabilities such as drag reduction, hypersonic missiles, logistically friendly distributed lighting systems and ship self defense techniques. Studies under this project examine methods of actively detecting, tracking, and containing submarines from manned, unmanned, surface, air, and underwater vessels, or a combination of such platforms, as well as more passive methods of sensing and recognizing changes in the marine environment.

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

|                         |         |         |         |
|-------------------------|---------|---------|---------|
|                         | FY 2003 | FY 2004 | FY 2005 |
| Friction Drag Reduction | 6.063   | 7.295   | 5.260   |

(U) The Friction Drag Reduction program is developing friction drag reduction technologies for surface ships and submersibles in the operational environment. The program will focus on methods known to reduce friction drag, such as injection of polymers, injection of microbubbles into the flow boundary layer, and the insertion of large air cavities over traditionally wetted surfaces. The goal is radical skin friction drag reduction sustained over operationally-relevant time periods. The program will address, by means of advanced computational and experimental techniques, the practical barriers to the implementation of polymer additives and microbubbles. This capability would allow dramatic decreases in fuel usage, increases in payload fraction and substantial enhancements in vehicle range and endurance and could lead to increased vessel speed.

(U) This program will also examine 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 no energy efficient, repeatable method has ever been validated. LFTC offers the potential to achieve revolutionary hydrodynamic performance improvements in

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military systems by actively controlling drag, turbulence, and friction. Other drag reduction techniques that are discovered by these investigations will also be explored; both for their friction reduction and for potential ship self defense capabilities.

(U) As a result of studying typical electrical layouts and distribution grids in Navy ships under the Lorentz Force Turbulence Control (LFTC) effort, an alternative application of electricity based technology has been initiated. FY 2004 and subsequent fiscal funding for this effort, now entitled the Electric Curtain program, is budgeted in a separate line in this project.

(U) Program Plans:

- Performed drag reduction tests of LFTC tiles.
- Developed a sound theoretical understanding of the underlying mechanisms of friction drag reduction using first-principles codes and small-scale experiments.
- Develop 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.
- Finalize buoyancy test vehicle design and efficiency.
- Develop a preliminary test plan for full-scale buoyancy test vehicle experiment.
- Conduct a full-scale buoyancy test vehicle experiment to provide high-quality data at large scales in order to validate the models.
- Conduct large-scale experiments to provide high-quality data at large scales in order to validate the predictive design tools.
- 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.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Surface Warfare Automated Shiphandling (SWASH) | 0.000   | 0.000   | 5.400   |

(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 will occur. SWASH will enable safe operations in an expanded sea state envelope.

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SWASH combines detailed sensing and wave prediction of the local sea surface with improved understanding of vessel dynamics in a control system that provides optimum course and speed to the vessel’s rudder and engines. SWASH offers the potential to reduce injuries to crew and passengers as well as damage to vessels caused by high waves. In addition, SWASH is an enabling technology for unmanned surface vessels (USVs), which will be a component of the modules for the Navy’s new Littoral Combat Ships (LCS). SWASH will increase the survivability and operability of USVs in rough seas, and can provide inputs to the LCS steering system to make USV launch and recovery faster and safer. Medium manned vessels, such as LCS, DD(X), and current classes, will benefit from the more detailed knowledge of wave fields that will be developed in the SWASH program. Sophisticated steering strategies can reduce damage to the vessels caused by high waves, and improve human performance by reducing vessel motions.

(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, followed by at-sea testing.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Hypersonics Flight Demonstration (HyFly) | 16.991  | 22.099  | 19.615  |

(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 ram-jet 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

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techniques. DARPA and the Navy established a joint program to pursue areas of the hypersonics program that would be relevant to maritime applications.

(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 (600 nmi).

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| High Efficiency Distributed Lighting (HEDLight) | 0.000   | 6.188   | 6.700   |

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

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(U) As a result of studying typical electrical layouts and distribution grids in Navy ships under this effort, an alternative application of electricity based technology has been developed and will be funded under the Electric Curtain program which is budgeted in a separate line in this project.

- (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.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Center of Excellence for Research in Ocean Sciences (CEROS) | 5.692   | 7.000   | 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.
  - Transitioned appropriate products to military use.



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|                  | FY 2003 | FY 2004 | FY 2005 |
|------------------|---------|---------|---------|
| Electric Curtain | 0.000   | 5.031   | 5.848   |

(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. Based on promising results investigated under the Lorentz Force Turbulence Control (LFTC) project under the Friction Drag Reduction program and the HEDLight program (both of which are budgeted in separate lines in this project), the Electric Curtain 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 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Electric Field Signature Sensors | 0.000   | 0.000   | 3.990   |

(U) The Electric Field Signature Sensors program will develop passive detection and targeting systems for maritime applications. Ordinary surface and subsurface motion causes disruptions in the earth’s naturally present electrostatic field that can be detected with highly sensitive sensors. The goal of this program is to exploit this E-field phenomenon through the integration and demonstration of enabling technologies in tactically relevant systems. Such systems will dramatically increase combat situational awareness and directly contribute to enhanced defensive

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and offensive operational capabilities. Potential applications include counter small-arms systems for helicopters, surface contact situational awareness systems for submarines, and Anti-Submarine Warfare.

- (U) **Program Plans:**
- Characterize electrostatic signatures within the battlespace environment.
  - Conduct operational concept development and analysis for multiple mission applications.
  - Develop low cost electrostatic sensors for a robust military environment.
  - Design, fabricate, integrate, and test in an tactically relevant system application.

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

|   |         |         |         |
|---|---------|---------|---------|
| Hypersonics Flight Demonstration                                      | FY 2003 | FY 2004 | FY 2005 |
| PE 0602114N, PE 0603114N, PE 0603123N, Navy, Office of Naval Research | 20.000  | 20.000  | 15.000  |

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Advanced Land Systems Technology TT-04                                       | 34.910  | 40.028  | 69.397   | 97.979  | 97.311  | 100.463               | 88.246  |

(U) **Mission Description:**

(U) This project is developing technologies for enhancing U.S. military effectiveness and survivability in operations ranging from force-on-force conflict to military Operations-Other-Than-War. 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, Anti-Sniper, and Vertical Infiltration, Persistent Extraction Robot (VIPER).

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

|                                    |         |         |         |
|------------------------------------|---------|---------|---------|
|                                    | FY 2003 | FY 2004 | FY 2005 |
| Novel Sensors for Force Protection | 11.784  | 8.719   | 12.810  |

(U) The Novel Sensors for Force Protection program (formerly known as the Close-In Sensing Program) is exploring and developing a variety of novel methods that will contribute to enhance protection of U.S. warfighters. Concepts for the projects originated in DARPA's Close-In Sensing program and have now matured into specific approaches that have been heavily influenced by situations encountered by U.S. warfighters in the Global War on Terrorism, Operation Enduring Freedom and Operation Iraqi Freedom. The motivation behind all 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 technologies investigated in Close-In Sensing considered new hardware and approaches to detect traditionally low signal-to-noise or concealed targets without placing people in harm's way and include infiltration and exfiltration technologies to incorporate sensor data reachback capability. 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 the Anti Sniper Project. Because of the multiple potential uses beyond close-in sensing in urban

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environments the Dynamic Optical Tags Program (DOTS), which was previously budgeted in this section in FYs 2003 through 2005 under the Close-In Sensing Program, has been delineated into its own narrative elsewhere in this PE/Project.

(U) The objective of the Unique Signature Detection Project is to determine 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 individuals. The program leverages research that demonstrated the same set of genes that code for internal immune system self/non-self recognition in mice, the Major Histocompatibility Complex (MHC), also code for unique emanated signatures. Although experimental data for humans is far less quantitative, behavioral studies have yielded compelling results to suggest that such phenomenology can also be expected in humans. Recent experimental results with mice suggest that MHC-determined urinary signatures are expressed in a mixture of volatile carboxylic acids occurring in relative concentrations that are characteristic of the emanation. This suggests the possibility of a corresponding unique and exploitable chemosignal. Accordingly, the program will design detectors that exploit this phenomenon by reliably detecting and identifying specific signatures of interest. The program will first characterize the nature of the signal, and determine its robustness in the presence of background signals. If an exploitable robust signature is identified, the program will then pursue detector development. Such detectors would enable U.S. troops to remotely detect the presence of high-level-of-interest individuals within groups of enemy troops or combatants with high reliability.

(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 and therefore would be common to all enemy dismounted troops or combatants, 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. This program first seeks to observe operation of organic sensing modalities in order to develop a fundamental understanding of these chemical emissions and their relationship to enemy troops or combatants. With this knowledge, a sensor and detection scheme can be developed that will be capable and robust against false alarms. This detection capability would provide advanced threat warning 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. The envisioned system is an array of UAVs surrounding the location of interest (building, wooded area, etc.). Each node of the array carries a

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suite of low-power multi-spectral 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 a system of 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 and similar tactics faced by troops in the field.

(U) Program Plans:

- Close-In Sensing.
  - Continued trade off studies in advanced technologies for use in data infiltration and exfiltration.
  - Evaluated novel delivery methods and platforms to enable target proximate access of sensor systems, including robotic and fiber optic technologies.
  - Explored multi-sensor architectures and waveforms.
  - Explored novel radio frequency exploitation concepts.
  - Investigated sensor reachback technologies.
- Unique Signatures Detection.
  - Identify the chemical make-up of 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.
  - Examine chemical emissions that are unique to humans and therefore to all enemy dismounted troops and combatants.
  - Examine background chemical signals in a variety of environments.
  - Design detectors capable of reliably indicating the presence of enemy dismounted troops and combatants with a low false alarm rate.

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- 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 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.

|                             | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------|---------|---------|---------|
| Dynamic Optical Tags (DOTS) | 2.584   | 5.947   | 8.819   |

(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. The program was budgeted under the Close In Sensing program but has now been broken out separately for enhanced visibility. 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.

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- (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 2003 | FY 2004 | FY 2005 |
|--------------------|---------|---------|---------|
| Guided Projectiles | 13.589  | 10.868  | 15.977  |

(U) The Guided Projectiles program is developing and demonstrating highly maneuverable gun-launched projectiles, 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 has been combined with the Collaborative Munitions efforts, which seek to expand the functionality and lethality of munitions by enabling new ways for them to collectively accomplish difficult and time critical missions, and are based on the success of the Antipersonnel Landmines Alternatives (APLA) program (completed in FY 2002). This program will also develop enabling technologies to give U.S. warfighters the ability to allow weapons platforms, such as mortars, 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. This program will adapt recent advances in communications, computers, ad-hoc 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) Specifically, the program seeks to develop a low-cost, non-imaging optical laser seeker using new technology. The goal is to replace the current 60mm mortar fuze with the laser seeker. This will greatly 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. Additionally, the program will exploit dismounted, close-in attack scenarios to 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



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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 control/steering fin system.
- Combine seeker with control/steering system into a package that replaces the current fuze on the 60mm mortar high explosive round.
- 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.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Networking Extreme Environments (NetEx) | 6.953   | 5.858   | 8.425   |

(U) The Networking in Extreme Environments (NetEx) program will create a wireless networking technology for the military user that enables robust connectivity in harsh environments and support its integration into 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 Multilateral Geolocation Ranging.
- Develop a Low Bit Rate Sensor Network with highly accurate geolocation.
- 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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Stimulated Isomer Energy Release (SIER) | 0.000   | 3.000   | 4.000   |

(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. It will develop a way to make these isomers in

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gram-size quantities. 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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| MAGneto Hydrodynamic Explosive Munition (MAHEM) | 0.000   | 0.000   | 4.200   |

(U) Based on concepts identified under the collaborative munitions program (budgeted under this PE/Project), 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 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.

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- (U) Program Plans:
- Refine magneto hydrodynamic 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

|                          | FY 2003 | FY 2004 | FY 2005 |
|--------------------------|---------|---------|---------|
| Compact Military Engines | 0.000   | 2.000   | 6.066   |

(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 engine types and diverse missions. The 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.

- (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.

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|            | FY 2003 | FY 2004 | FY 2005 |
|------------|---------|---------|---------|
| CrossHairs | 0.000   | 1.636   | 4.000   |

(U) This program will apply the techniques developed in the Novel Sensors program to rapidly 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 high-speed IR imaging to determine bullet and RPG trajectories and backtrack to shooter origin, automated responses such as imaging for forensic and judicial evidence, rapid dissemination of shot location to combatants to allow both effective concealment and counterfire, protective measures against RPGs followed by counterfire, and elimination of threats. The Concept of Operations is to provide HUMMWV mounted detection and response systems 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, quick reactive sensor techniques for a 360 degrees azimuth and 60 degree elevation detection zone; robust data collection for tracking firing source; and fast response solutions. The program will culminate with a series of prototype demonstrations of the system(s) in typical combat environments.

(U) Program Plans:

- Develop fast response system concepts in coordination with user input.
- Identify and develop ultra-fast sensors and algorithms to detect and track in near real time.
- Perform component testing and conduct detection and tracking demonstrations.
- Analyze data and integrate response system.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Vertical Infiltration, Persistent Extraction Robot (VIPER) | 0.000   | 2.000   | 5.100   |

(U) This program will apply concepts from the Novel Sensors program to the development of a serpentine platform with a small body diameter and three-dimensional mobility. The VIPER platform will be able to support a variety of operational missions including surveillance of areas that are beyond the reach of current robotic platforms, as well as sensing, searching and providing the warfighter with information that cannot be obtained by current systems. Technical 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; system infiltration and data exfiltration; health and status monitoring; and position and configuration management. Solutions to these challenges will be developed to support urban operation concepts.

(U) Program Plans:

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

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Advanced Tactical Technology TT-06   | 64.030  | 90.703  | 112.287  | 116.767 | 119.141 | 133.673               | 133.530 |

(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 2003 | FY 2004 | FY 2005 |
| High Power Fiber Lasers | 6.954   | 11.787  | 13.770  |

(U) The High Power Fiber Lasers program will develop and demonstrate single mode fiber lasers with output powers of 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 polarized 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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| High Powered Femto Second Laser Diodes | 5.632   | 3.285   | 3.151   |

(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 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 ability of femtosecond laser to micromachine complex Defense parts.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Super High Efficiency Diode Sources (SHEDS) | 1.790   | 6.770   | 4.801   |

(U) The goal of the SHEDS (formerly High Average Power Solid State Laser) 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 and neodymium 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 spectral range of 880nm to 980nm, the range for pumping directly into the upper laser level of Nd and Yb.
- Provide wavelength stabilization to prevent thermal drift of the diode bar wavelength outside of the range of high absorption of the laser transition.
- Achieve a power level of 480W/cm<sup>2</sup> per diode stack operating continuously.
- Achieve a peak power of 2000W/cm<sup>2</sup> 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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| High Energy Liquid Laser Area Defense System (HELLADS) | 5.221   | 10.804  | 20.841  |

(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 10-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 2003 | FY 2004 | FY 2005 |
|------------|---------|---------|---------|
| Laser Star | 3.340   | 8.476   | 5.885   |

(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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Coherent Communications, Imaging and Targeting | 5.518   | 8.872   | 12.800  |

(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.

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(U) The high data-rate optical communications project will exploit the characteristics of CCIT SLMs to dynamically generate orbital angular momentum (OAM) of photons. Using SLMS to change the OAM of photons in real-time as opposed to simply modulating the amplitude of light waves allows for significant improvement in data carrying capacity. The program will also develop system level architectures for secure free space optical communication networks.

(U) Program Plans:

- Develop 256x256 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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| High Performance Algorithm Development/Virtual Electromagnetic Test Range | 10.116  | 11.775  | 13.409  |

(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

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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.

(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. Expand to include dynamic and rough-surface scatterers with particular emphasis on radar signature prediction and design for naval vessels.
- 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.
- Apply modern algorithmic approaches to battlefield modeling using stochastic, algebraic, and differential equations as well as Hidden Markov Models.
- Develop approaches to software design and optimization to dramatically reduce time and cost of the production of high-performance software for sensing and communications systems.

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|                                   | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Integrated Sensing and Processing | 8.494   | 8.697   | 8.139   |

(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 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Mission Specific Processing (MSP) | 6.720   | 4.527   | 4.023   |

(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.

(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.
- Begin development of 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.
- Conduct 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.
- Complete a demonstration that addresses system level issues and quantifies the increased performance relative to semi-custom ASIC designs, field programmable gate arrays (FPGAs), and commercial off the shelf (COTS) processors.



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|              | FY 2003 | FY 2004 | FY 2005 |
|--------------|---------|---------|---------|
| Water Rocket | 3.355   | 1.203   | 0.000   |

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

(U) Program Plans:

- Perform critical technology demonstrations and analysis of the system for the regenerative fuel cell and other developmental components.
- Design, fabricate, and test a baseboard regenerative fuel cell system demonstrating performance and endurance.

|                      | FY 2003 | FY 2004 | FY 2005 |
|----------------------|---------|---------|---------|
| Training Superiority | 5.950   | 12.338  | 15.029  |

(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.

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- (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).
  - 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.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Language and Speech Exploitation of Resources Advanced Concept Technology Demo | 0.940   | 0.688   | 0.129   |

(U) DARPA’s Babylon program is providing research and development to support speech translation on small platforms for military-critical languages. The speech integrated product team of the Language and Speech Exploitation of Resources Advanced Concept Technology Demonstration (ACTD) seeks to transition this technology into ACTD-supported military utility assessments (MUAs). One of the competitively selected DARPA developers has developed and perfected a technology for information extraction that will be applied for the first time to speech translation. This technology will allow flexible and accurate translation of varying utterances without requiring recognition and translation of every word in the utterance.

- (U) Program Plans:
- Refine capabilities of the two-way translator for testing in MUAs.
  - Develop translator in Arabic dialect – a language for which substantial speech data have been collected and annotated as required to develop speech recognizers.
  - Integrate component technologies including:

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- Speech recognition in English and Arabic.
- Speech playback in Arabic and English.
- Information extraction and translation from Arabic to English.
- Port translator to a second critical language (e.g., Vietnamese, Thai), for which little annotated speech data is now available.
- Install translator on small, readily available platforms (e.g., laptops, handhelds).
- Test and evaluate in the service labs supporting the ACTD.
- Provide translators to the ACTD for MUAs.

|           | FY 2003 | FY 2004 | FY 2005 |
|-----------|---------|---------|---------|
| Air Laser | 0.000   | 0.000   | 6.000   |

(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 hundred kilowatt-class HEL which combines the advantages of chemical and solid state lasers and minimizes the disadvantages: it operates in the eye-safe wavelength regime; it uses liquid 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 4 kW laser design.
  - Develop and demonstrate 20kW laser design.
  - Develop 100 kW laser design.
  - Develop kilowatt-class red diodes.

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|                            | FY 2003 | FY 2004 | FY 2005 |
|----------------------------|---------|---------|---------|
| Rapid Checkpoint Screening | 0.000   | 1.481   | 4.310   |

(U) The Rapid Checkpoint Screening program (formerly Deception Detection funded from PE 0602301E, ST-28) 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.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Aeronautics Technology TT-07   | 21.739  | 16.229  | 41.760   | 46.377  | 39.314  | 29.285                | 29.256  |

(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 2003 | FY 2004 | FY 2005 |
| Micro Adaptive Flow Control (MAFC) | 9.614   | 7.172   | 7.200   |

(U) Micro Adaptive Flow Control (MAFC) technologies enable control of large-scale aerodynamic flows using small-scale actuators. MAFC technologies combine adaptive control strategies with advanced actuator concepts like micro-scale synthetic jets, microelectromechanical systems (MEMS)-based microactuators, pulsed-blowing, combustion actuators and smart structures to cause the delay, or prevention, of fluid flow separation. MAFC technologies will be explored for applications such as download and drag reduction for air vehicles, 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) The program is entering Phase III where three of the most promising applications will be evaluated in full-scale adaptive flow control demonstrations. The first Phase III demonstration took place in July 2003, and used synthetic jets on a tiltrotor aircraft placed in the flap and aileron to demonstrate flow control. This test reduced the download on the XV-15 by 14%. This amount of download reduction, if applied to the V-22, would enable a payload increase of 1000 lbs. Leading technical challenges include the development of robust actuators with the required force, displacement, and bandwidth for robust applications, and the integration of novel actuators including combustion gas actuation, phased

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plasma actuators, and synthetic jets with MEMS-based flow sensors and embedded, adaptive controllers. These challenges require the development of new approaches for power conditioning and distribution, and the definition and implementation of control system architectures, including embedded sensing, data communication, processing and actuation. A second Phase III demonstration of the Boeing High Frequency Excitation for Supersonic Weapons Release (HIFEX) system will be tested at Holloman Air Force Base on a rocket sled in 2005. This system will allow for safe weapons release at speeds in excess of Mach 2. The last Phase III demonstration will be the Georgia Tech Research Institute (GTRI) and Army Research Lab (ARL) Self Correcting Projectile for Infantry Operations (SCORPION); currently a piezo-electric actuated control system for 40mm grenades. Recent testing performed at the Aberdeen Proving Grounds in Aberdeen, MD demonstrated that firing the piezo-electric actuator against the weapon's coanda surface provides more than enough control authority to meet and exceed program goals. Three full-scale demos will take place in 2005 with an emphasis on moving towards smaller caliber and faster weapons. The actuation system will also be upgraded from piezo-electric to gas generating solid propellants.

(U) Technologies involving aerodynamic surface flow control will be further developed and refined under the Solid State Multifunctional Micro Air Vehicle (SSMAV) effort. SSMAV will provide an order of magnitude improvement in control authority to navigate in complex environments under gusts up to 20 mph by leveraging the use of solid state micro chemical thrusters (jets) embedded in the aerodynamic surface of the micro air vehicle. This will provide multi-functionality that enables the aerodynamic surface to serve as a source of lift as well as control and sensing. The jets are used to locally disturb the flow over the vehicle in the low Reynolds number regime to enable high maneuverability and precise navigation. In addition, the thrusters can be used to change the stall and drag properties of an air vehicle to rapidly slow it down from a glide trajectory to perch on the top of a building without being detected.

(U) Program Plans:

- Executed Phase II, high speed, closed loop technology demonstrations.
- Successfully executed MAFC download reduction testing on the XV-15.
- Continue to identify Phase III follow on efforts from the projects with the most promising Phase II results.
- Complete sled design and fabrication for 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.
- Evaluate advanced composite manufacturing techniques for air vehicles and flow control.

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- Develop SSMAV system level requirements, control authority, navigation accuracy.
- 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 6 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 2003 | FY 2004 | FY 2005 |
|---------------------------------------|---------|---------|---------|
| Small Scale Propulsion Systems (SSPS) | 8.125   | 3.057   | 3.000   |

(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.

(U) Program Plans:

- Demonstrate a liquid-fueled micro-rocket with turbopumps operating with 1.5kg thrust.
- Achieve diesel fuel operation of a novel crankless internal combustion engine.
- Demonstrate a valve-less, high-frequency pulse detonation engine.
- Demonstrate a 20:1 thrust to weight ratio on a small diesel-fueled turbojet engine.
- 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.



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|           | FY 2003 | FY 2004 | FY 2005 |
|-----------|---------|---------|---------|
| Peregrine | 0.000   | 0.000   | 1.410   |

(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. Unmanned air vehicles are an emerging threat. 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:
- System requirements definition.
  - Develop concept design.
  - Demonstrate aircraft performance and kill capability.

|        | FY 2003 | FY 2004 | FY 2005 |
|--------|---------|---------|---------|
| Walrus | 4.000   | 6.000   | 10.000  |

(U) Technologies previously reported under the Long Endurance Hydrogen Powered Unmanned Air Vehicle and the Unmanned Tilt Rotor programs have been combined into the Walrus program; these include: high-strength and low structural weight airframes; high efficiency propulsion systems; and heavy-lift cargo transport. The Walrus program will develop and evaluate a very large airlift vehicle concept that is designed to fly heavier-than-air, unlike earlier generation airships. As a "hybrid aircraft," it will generate lift through a combination of aerodynamics and gas buoyancy. The program will develop and construct a Walrus Advanced Technology Demonstration (ATD) air vehicle with

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comparable C-130 airlift capability, and will explore, develop, and demonstrate the system concepts of operation. Scalability of the concept will also be demonstrated. An objective vehicle is envisioned to be capable of lifting over 500 tons across intercontinental distances, being able to transport a Unit of Action (UA) from “Fort-to-Fight” as a complete integrated action-ready package of personnel and equipment. Additionally, Walrus may meet the multi-agency needs of common requirements for extended range airborne patrol, persistence and intra-theater support and re-supply. Two advanced breakthrough technologies that will be investigated in the first phase are: vacuum / air buoyancy compensator tanks, and electrostatic atmospheric ion propulsion. 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 development, design, build and initial flight test of the ATD vehicle. Funding is budgeted is PE0603285E, Project ASP-01 to continue the program past Phase I.

(U) Program Plans:

- System definition and development of notional objective air vehicle concept having a payload capability circa 500 tons.
- Establish the feasibility of breakthrough technologies.
- Develop conceptual designs of ATD air vehicles 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.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| High Speed / Hypersonic Reusable Demonstration | 0.000   | 0.000   | 15.000  |

(U) This initiative continues work to design, develop and demonstrate a combined cycle engine and reusable hypersonic cruiser, and will be conducted in conjunction with the Responsive Access, Small Cargo, Affordable Launch (RASCAL) and Force Application and Launch from CONUS (FALCON) programs (PE 0603285E, Project ASP-02). 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.

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- (U) Program Plans:
- Initiate design work for integration of combined cycle engine and reusable hypersonic vehicle with particular focus on engine maturation; combustion control systems; high temperature and leading edge materials; inlet concepts; and aerodynamic control mechanisms.

|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Helicopter Rotor Blade Quieting | 0.000   | 0.000   | 5.150   |

(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 harder to track and engage. The Helicopter Rotor Blade Quieting program will employ advanced technology to address this objective. Reducing acoustic signature without sacrificing performance requires a significant departure from current rotor blade designs. Because of the exorbitant cost associated with wind tunnel testing, novel blade design must rely on computational modeling to narrow down the experimental test matrix. Today's models are essentially empirical and therefore allow for only small excursions from existing blade designs. This program will address this barrier to novel blade design by leveraging recent advances in computational fluid dynamics (CFD) to develop physics-based predictive design tools that will yield blades with vastly improved acoustic characteristics. The predictive tools will be tested using existing data sets and data collected from fully instrumented small-scale experiments. The tools will then be used to design new blades that yield a significant reduction in low-frequency in-plane signatures compared to a baseline design.

- (U) Program Plans:
- Develop predictive blade design tools.
  - Validate models using experimental data.
  - Use the tools to design new blades that yield a significant reduction in low-frequency, in-plane signature.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Advanced Logistics Technology TT-10  | 19.401  | 19.662  | 15.000   | 0.000   | 0.000   | 0.000                 | 0.000   |

(U) **Mission Description:**

(U) The objective of the Advanced Logistics Technology project is to revolutionize the way the DoD plans, executes, monitors, and dynamically replans logistics support across the entire spectrum of operational environments from day-to-day routine peacetime operations to disaster relief, non-combatant evacuation, peacekeeping, peacemaking, and minor and major contingencies. The project involves the creation of a set of hardened functional information systems technologies and supporting business processes that support the development of military logistics applications that are survivable and secure even in the most hostile, chaotic wartime environments.

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

|          |         |         |         |
|----------|---------|---------|---------|
|          | FY 2003 | FY 2004 | FY 2005 |
| UltraLog | 19.401  | 19.662  | 15.000  |

(U) The UltraLog program provides technologies to make our highly distributed military logistics information systems inherently survivable even in the most hostile kinetic and cyber warfare environments. UltraLog's technical focus is to use intelligent agent technology to enhance the robustness, stability and security of the core military logistics data and information processing, thereby resulting in a resilient and trustworthy logistics system that can reliably adapt under harsh, dynamic conditions. UltraLog's strategy is to pursue survivability research breakthroughs in agent technology, and then validate them through integration into a large-scale logistics information system test-bed that supports highly detailed component-level and systems-level assessment. The technologies developed under UltraLog will ensure that future logistics information systems can survive directed cyber attack (technologies include: dynamic Public Key Infrastructure management, information rovers, pedigree, dynamic policy-based control, and random routing); can sustain operations in a chaotic kinetic warfare environment (technologies include: non-local persistence, distributed consistency checking, agent-based fault tolerance, and dynamic communications-aware redundancy and adaptation); and deal with the complexity of multiple current operations ranging in tempo from peacetime training to major regional contingencies with proper

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management of plans and priorities (technologies include: assured convergence, adaptive configuration, variable fidelity processes and reactive plan-space management).

(U) **Program Plans:**

- Develop, integrate and evaluate technologies providing dynamic information security and agent system survivability for sustained wartime logistics operations in a harsh kinetic and information warfare environment.
- Conduct rigorous assessments by external, independent evaluation teams to verify and validate the concept of operations and technical architecture of the approach, as well as establish specific system component survivability and overall logistics systems functionality under stress.
- Create a prototype 1000-agent logistics information system that is capable of operating under directed adversary cyber attack and absorbing significant infrastructure loss, with acceptable capabilities and performance degradation during high-tempo military operations.
- Develop, integrate and evaluate technologies to control and optimize the overall supply flow and inventory strategies for logistics support across the joint battlefield, allowing different commodity chains to operate as complex adaptive networks, rather than as fixed logistics chains.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005 | FY 2006  | FY 2007 | FY 2008               | FY 2009 |
| Network Centric Enabling Technology TT-13                                    | 0.000   | 33.170  | 53.918  | 68.431   | 71.329  | 74.189                | 88.744  |

(U) **Mission Description:**

(U) This project provides technology to build mission applications explicitly tailored to network-centric system architectures. Mission applications include signal processing, detection, tracking, identification, planning, and control functions. These applications will integrate: (1) external sensors that provide data on targets and their mission contexts; (2) external platforms, both air and surface, that deliver sensors and munitions to designated areas; and (3) external communications networks that provide connectivity between computing nodes located on the platforms, at field command centers, and at headquarters. The mission applications share data to form consistent operating pictures of the battlespace, tailored to the needs of commanders at each node. They also negotiate plans for future operations based on mission needs presented at each node. To maintain focus on operationally relevant problems, the technical goals are posed and evaluated in the context of robotic forces. These are defined as collections of a few dozen robotic platforms whose operations must be coordinated to achieve specified mission goals.

(U) Technologies developed in this project enable localized, distributed and cross-platform collaborative processing. This allows networks of sensors to rapidly adapt to changing force mixes, communications connectivity and mission objectives. 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; (2) consistent integration of target and environment information; and (3) flexible operational tactics and procedures for finding evasive targets in difficult environments.

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

|                                     |         |         |         |
|-------------------------------------|---------|---------|---------|
|                                     | FY 2003 | FY 2004 | FY 2005 |
| Network Embedded Systems Technology | 0.000   | 15.293  | 15.255  |

(U) The Networked Embedded Systems Technology (NEST) program provides robust coordination and synthesis services for sensor network systems. These are the key software building blocks needed to enable ad hoc or structured sensor networks consisting of elementary nodes to

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work 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, helmet- or vehicle-mounted sensor arrays for detecting being painted by laser and targeting the source, wide area 24/7 surveillance of long linear structures such as pipelines and borders, etc. These applications require anywhere 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 all such applications. This program was previously funded in PE 0602301E, Project ST-19 in FY 2002 and FY 2003.

(U) Program Plans:

- Design deterministic and probabilistic methods for self-stabilizing protocols for lightweight coordination services such as global clock synchronization, sensor localization, etc.
- Develop design tools for the customization of coordination-services to specific applications based on application requirements and platform characteristics.
- Develop formal modeling and verification techniques for coordination-services and for integrating them.
- 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., for actuator firing sequences) and services (e.g., for 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 such networks.

|                              | FY 2003 | FY 2004 | FY 2005 |
|------------------------------|---------|---------|---------|
| Combat Zones That See (CZTS) | 0.000   | 0.000   | 6.213   |

(U) The Combat Zones That See (CZTS) project improves force protection for warfighters in foreign urban environments. CZTS provides close-in sensing and extended reconnaissance capabilities using a network of video sensors. CZTS tracks vehicles over wide urban areas using sparse arrays of video cameras, and automatically detects vehicles that may be involved in hostile activities based on the observed tracks. This

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network will produce far too much data for human analysis, so advanced video understanding algorithms embedded in commercial-off-the-shelf hardware systems will monitor video feeds automatically. Reconnaissance, surveillance, 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 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 from unmanned aerial vehicles.

(U) Program Plans:

- Develop, install and evaluate a Force Protection prototype, on a 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.

|                             | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------|---------|---------|---------|
| Automated Battle Management | 0.000   | 9.800   | 15.800  |

(U) The pace of battle will continue to increase as more capable platforms, and more effective communication networks, become operational. While experienced commanders will always be needed to formulate strategy and select tactics, the increased pace of battle will require 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 develops novel technologies for multi-platform, automated battle management at the tactical level, in the air, on the ground, and within mobile sensor networks.



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- The Mixed Initiative Control of Automa-teams (MICA) program develops algorithms, software, modeling and simulation capabilities to perform multi-level planning, assessment and control of distributed, autonomous combat forces. MICA provides a commander with the operational and mission planning tools to select optimal team composition, to perform dynamic tasking and re-tasking of teams, and to generate cooperative routes for autonomous Unmanned Air Vehicles in stressful operational missions, especially suppression of enemy air defenses. Mixed initiative control will develop collaborative strategies and tactics for these teams under the supervision of a single human operator, with adjustable autonomy determining the degree of human authority desired or required during task execution. Through the exploitation of control science metrics for stability, performance and robustness, these teams of cooperative, autonomous vehicles such as Unmanned Combat Air Vehicles will accommodate uncertainty in both the operating environment and feedback information, as well as address the presence of an intelligent adversary and fixed/mobile threats in the battlespace. An open experimental platform will be employed to evaluate these hierarchical battle management and control methodologies with humans-in-the-loop, initially in a simulation and subsequently in a hardware demonstration.
  
- The Organic Ground Battle Management program is an outgrowth of the Mixed Initiative Control of Automa-Teams (MICA) program. It will enable continuously synchronized reconnaissance, surveillance, and targeting in highly automated ground operations. It accommodates warfighter maneuver, fires and communications. The program develops methods of rapid search for threats. Threat search considers: mission plan, responsive collection of data on local terrain features for route planning, automated search for obstacles and barriers, adjustment of maneuver plan as surveillance results appear, generation of routes around unsearchable threat areas, and positioning and repositioning of communications relays. The program develops techniques for employment of indirect fire as probes. It automates the weapon-to-target assignment and provides integrated weapon guidance and re-assignment. The Organic Ground Battle Management effort will speed insertion of automated ground forces. It promises reduced forward staffing and a leaner logistical trail as it increases the speed and effectiveness of missions to eliminate or avoid threats. The program supports integrated planning of manned and robotic forces while enabling small staffs to produce quality plans and actions.
  
- The Organic Sensor Exploitation Network (OSEN) program will develop rapid, highly autonomous techniques for sensor exploitation, leveraging technology from the NEST program and support autonomous sensor networks in ground warfare. It is developing technology to: (1) permit on-board exploitation of sensor data from remotely deployed sensor nodes; (2) support correlation of information developed across different platforms; (3) detect, track and identify targets in the field of view of a platform; (4) cue other sensors to acquire a target; and (5) hand off targets to other platforms as targets move through different 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 that may be fixed or mounted on mobile

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platforms. The program accommodates variable communications connectivity; models predict changes caused by line-of-sight occlusions. 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.

(U) Program Plans:

- Mixed Initiative Control of Automa-teams
  - Apply and refine algorithms and software to assign autonomous combat vehicles to task-oriented teams.
  - Apply and refine algorithms and software to assign mission-derived subtasks to each combat vehicle in a team.
  - Apply and refine algorithms and software to generate event schedules and collaborative routes for each combat vehicle in a team, with collision avoidance and self-reorganization in the presence of fixed/mobile threats.
  - Apply and refine algorithms and software supporting dialog between human commanders/operators and semi-autonomous entities to communicate recommended courses of action, appropriate feedback information and decision tuning parameters.
  - Deploy a third phase open experimental simulation platform stressing multi-team coordination and cooperative planning of sensor and weapon platforms against difficult ground targets with responsive operator control and intervention.
  - Demonstrate cooperative management of 2-5 teams of 5-10 platforms and one operator with team self-organization in the presence of active threats.
- Organic Ground Battle Management
  - Extend recent advances in distributed resource management to address ground warfare.
  - Develop additional adversarial reasoning techniques to anticipate enemy responses.
  - Evaluate results with non-operational robotic platforms at a ground warfare training facility.
- 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 that is adaptable to the devices present at that node.
  - Prototype candidate algorithms for each function (search, detect, track, identify, correlation, handoff) based on alternative technologies.

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- Evaluate candidate algorithms in a synthetic environment to calibrate and verify performance models.
- Insert selected algorithms into a hardware-in-the-loop testbed. Demonstrate practical utility and verify system performance.

|                | FY 2003 | FY 2004 | FY 2005 |
|----------------|---------|---------|---------|
| Eyes-On System | 0.000   | 3.132   | 5.350   |

(U) The goal of the Eyes-On (EyO) 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. Pre-surveying 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 fly-out. 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 tradeoff curves.
  - Simulate each design over a suite of missions, and select the one 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 complete prototype systems.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Urban Warfare Robotic Surveillance (URS) | 0.000   | 0.000   | 2.000   |

(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 multipath propagation, limited lines of sight and frequent obscuration. Platforms and sensor networks are designed to operate in urban exterior, underground and indoor environments. Communications repeaters and routers are included for terrestrial connectivity to all platforms. They 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 2003 | FY 2004 | FY 2005 |
|------------|---------|---------|---------|
| Home Field | 0.000   | 0.000   | 3.500   |

(U) The Home Field program will develop sensor and sensor control networks that rapidly and reliably acquire all the information needed to plan and execute military operations. It will acquire information with sufficient detail and accuracy to take away 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 be derived that will maximize coverage and minimize detectability. It will build high fidelity multiphenomenological bases for change detection that can cue searches for targets, and anticipate changes due to current or impending meteorological events. Real-time context information to sensor managers, maneuver controllers, weapons operators, and commanders will be supplied. The program will help filter natural change from artificial change indicative of human (threat) activity. It will 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. Finally, Home Field will provide selective, highly detailed context information to commanders of field units, and to battle management systems for unmanned ground forces.

(U) Program Plans:

- Demonstrate a 3D model construction method that can use distributed video cameras operating in a mixed contrast 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 prototype planning tools that leverage the extracted urban feature set.
- Demonstrate a model update approach that keeps the urban cartographic representation current.

|                                       | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------------|---------|---------|---------|
| Adaptive Reflexive Middleware Systems | 0.000   | 4.945   | 5.800   |

(U) The Adaptive and Reflective Middleware Systems (ARMS) program develops fully integrated open system computing and information architecture. Initial focus is on the Total Ship Computing Environment (TSCE) in the DD(X) Future Surface Combatant Family of Ships. The

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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 sub-system 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 between remote entities. For this it employs advanced Quality of Service (QoS) capabilities of the underlying network and end systems. ARMS was previously funded in PE 0602302E, Project AE-01.

(U) **Program Plans:**

- Define and prototype adaptive protocols, algorithms, patterns, and tools. Goals are (1) to enforce security policies to enhance and support secure global resource allocation, scheduling, and control; and (2) to ensure stability and dependability across multi-level feedback loops in the network-centric TSCE.
- Develop robust meta-programming policies and mechanisms based on standard middleware.
- Demonstrate the dynamic flexibility and QoS in the second DDX TSCE baseline.
- Define and prototype reflective techniques for synthesizing optimized distributed, real-time, and embedded middleware.
- Develop required languages, algorithms, and tools. Configure customizable, standards-compliant TSCE middleware and applications.
- Develop robust adaptive protocols, algorithms, patterns, and tools based on standard middleware. Demonstrate that they can enforce the security policies for global resource allocation, scheduling, and control in the third DDX TSCE baseline.
- Develop and demonstrate robust reflective techniques for synthesizing optimized standards-based middleware in the fourth DDX TSCE baseline.
- Develop and capture design expertise in pattern languages. Formalize the successful techniques and constraints associated with building, generating, and validating QoS-enabled middleware frameworks and protocol/service components for the DDX TSCE baselines.
- Demonstrate mature, standards-based middleware technologies for transition to the DD(X) Surface Combatant Family of Ships.

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

- Not Applicable.

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| <b>COST (In Millions)</b>   | <b>FY 2003</b> | <b>FY2004</b> | <b>FY2005</b>  | <b>FY 2006</b> | <b>FY 2007</b> | <b>FY 2008</b>               | <b>FY 2009</b> |
| Total Program Element (PE) Cost   | 414.437        | 465.450       | 502.044  | 486.485        | 495.035        | 496.154                      | 496.821        |
| Materials Processing Technology MPT-01  | 126.158        | 128.857       | 159.478  | 150.495        | 158.006        | 160.139                      | 163.728        |
| Microelectronic Device Technologies MPT-02  | 135.911        | 169.709       | 190.881  | 205.018        | 226.203        | 233.922                      | 239.076        |
| Cryogenic Electronics MPT-06  | 6.895          | 4.911         | 0.000  | 0.000          | 0.000          | 0.000                        | 0.000          |
| Beyond Silicon MPT-08   | 80.152         | 83.976        | 61.827   | 34.570         | 28.657         | 16.000                       | 16.000         |
| Biologically Based Materials and Devices MPT-09                                     | 65.321         | 77.997        | 89.858   | 96.402         | 82.169         | 86.093                       | 78.017         |

**(U) Mission Description:**

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

(U) The 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) Advances in microelectronic device technologies, including digital, analog, photonic and microelectromechanical (MEMS) devices, continue to have significant impact in support of defense technologies for improved weapons effectiveness, improved intelligence capabilities and for enabling information superiority. The Microelectronics Device Technologies Project supports the continued advancement of these technologies through the development of performance driven advanced capabilities, exceeding that available through commercial sources, in



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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 Cryogenic Electronics project funds specific applications of thin-film electromagnetic materials in electronic devices and circuitry for military applications. Thin-film electromagnetic materials have reached a stage of development where specific applications can be identified in electronic devices and circuitry for military systems. This project draws to a close at the end of FY 2004, a reflection of the maturity level that DARPA has obtained in cryogenic electronic technology development and sub system insertion. Any further integration of this technology into weapon/sensor systems will be budgeted in the respective platform's PE and projects.

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

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

| <b>(U) <u>Program Change Summary:</u> <i>(In Millions)</i></b> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|--|-----------------------|-----------------------|----------------------|
| Previous President's Budget                                    | 434.426               | 465.544               | 461.043              |
| Current President's Budget                                     | 414.437               | 465.450               | 502.044              |
| Total Adjustments  | -19.989               | -0.094                | +41.001              |

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|                                  | <u><b>FY 2003</b></u> | <u><b>FY 2004</b></u> |
|----------------------------------|-----------------------|-----------------------|
| Congressional program reductions | 0.000                 | -19.994               |
| Congressional increases          | 0.000                 | 19.900                |
| Reprogrammings                   | -0.250                | 0.000                 |
| SBIR/STTR transfer               | -19.739               | 0.000                 |

**(U) Change Summary Explanation:**

|         |  |
|---------|--|
| FY 2003 | Decreases reflect SBIR transfer and minor reprogramming.   |
| FY 2004 | Decrease reflects congressional program reductions to Biochemical Materials (MPT-09), Intelligent Digitization of Analog Sensors (MPT-02) and undistributed reductions offset by adds in the areas of optoelectronics, strategic and advanced materials, cryo-power, heat actuated coolers, 3D structures, friction stir welding and nanotechnology. |
| FY 2005 | Increase reflects additional efforts in the functional materials programs, additional microelectronics efforts, new biology efforts and additional funds being added to the Focused Quantum Systems Initiative.  |

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Materials Processing Technology, MPT-01                                      | 126.158 | 128.857 | 159.478  | 150.495 | 158.006 | 160.139               | 163.728 |

(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.

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

|                                  |         |         |         |
|----------------------------------|---------|---------|---------|
|                                  | FY 2003 | FY 2004 | FY 2005 |
| Structural Materials and Devices | 32.828  | 34.000  | 45.100  |

(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, and spacecraft structures. Approaches are also being developed for reducing the risk of introducing new materials in defense acquisitions and maintaining them in the field. Techniques are being established for assessing damage evolution and predicting future performance of the structural materials in Defense platforms/systems through physics-based models and advanced interrogation tools. New, low cost processing and fabrication techniques are also being developed to enable expanded use of new materials and structures in Defense applications as well as to produce novel materials that cannot be made through conventional processing approaches.

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(U) Program Plans:

- Develop multifunctional materials concepts designed to provide significant improvement in the capabilities of Defense systems by providing additional functions (e.g., self-healing, thermal control, blast protection, and power) to load bearing structures, quantify their performance and fabricate specific prototype systems.
- Develop and verify models that predict bulk amorphous metal formation and behavior; use these models to produce bulk amorphous materials 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).
- Apply the accelerated insertion methodology to new materials that, if inserted, will significantly improve Defense systems.
- 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 for 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 structural materials of interest to Defense, especially titanium.
- 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 processing approaches for making materials and structures of interest to DoD (GRIN Lenses, high temperature structures, high temperature actuators).

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|                               | FY 2003 | FY 2004 | FY 2005 |
|-------------------------------|---------|---------|---------|
| Smart Materials and Actuators | 28.930  | 32.007  | 37.000  |

(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. New piezoelectric materials are being developed that will dramatically increase the performance of Navy sonar/systems. “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 theatre of operations.

(U) Program Plans:

- Demonstrate enhanced Naval sonar device/system performance using piezocrystals over a spectrum of representative applications on the laboratory scale, and for a selected few applications on the field scale.
- Develop exoskeleton architectures that are kinematically and dynamically compatible with human physiology.
- 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.
- 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.
- Develop ultra-light high temperature capable materials systems for hypersonic vehicles incorporating magnetic features to enable reduced thermal load, boundary layer control and virtual shape control.
- Develop materials and devices to enable personnel access to rooftops and upper story windows and, in cooperation with the Services, develop fieldable systems for use in urban operations.

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- Develop materials, devices, and systems for urban conflict including compact, expandable barriers, tamper resistant or tamper evident door and window coverings, and traction reducing agents for impeding foot and wheeled traffic.

|                                  | FY 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Functional Materials and Devices | 25.000  | 25.000  | 37.200  |

(U) In this program, new materials and concepts are being applied to the development of functional materials and devices. This includes advanced magnetic materials for high sensitivity, magnetic field sensors; non-volatile, radiation-hardened magnetic memories with very high density, short access time, infinite cycleability and low power; novel materials and device structures for high frequency acoustic imaging; and electroactive polymers for sensing, actuating, and analog processing. New permanent magnetic materials with significantly higher magnetic strength and higher operating temperature for motors, generators, flywheels, bearings and actuators are also being explored. Unique 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. Technology for the mask-less, direct-write of mesoscopic integrated conformal electronics will enable the three-dimensional integration of both active and passive components, significantly reducing the size, weight and cost of integrated electronics functions (circuits, batteries, antennae, etc.).

(U) Program Plans:

- Demonstrate frequency and phase agile antennas, filters, phase shifters, and matching elements and transition to Army and Navy communication and remote sensing applications.
- Demonstrate both 1Mbit standalone Magnetic Random Access Memory (MRAM) at high density and high speed and lower density radiation-hard embedded memory and transition to Navy Strategic Programs and DTRA.
- Demonstrate the ability to direct write mesoscale (10 microns to 1 mm) electronic circuitry, both passive and active (transistors, filters, etc.), conformally, on low temperature substrates (plastic, paper, etc.), using computer aided design/computer aided manufacturing (CAD/CAM) software.
- Develop and demonstrate novel magnetic meta-materials 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 (> 30 MGOe for isotropic systems and > 60 MGOe for anisotropic systems) for DoD motor applications.

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- Develop and demonstrate novel microwave meta-materials (including artificial ferrites, nanocomposite ferroelectrics, artificial magnetodielectrics, and negative index materials) that will enable novel antenna and radar designs with reduced size and improved bandwidth and efficiency.
- Develop smart, multifunctional fibers (e.g., fibers that incorporate power, electro-magnetic behavior, actuating and sensing functions) 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.
- 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.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Materials for Logistics (Air, Water, Power) | 34.000  | 32.900  | 40.178  |

(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. The feasibility of open ocean, littoral and freshwater prototype fuel cell systems, capable of generating continuous, unattended electrical power for greater than 10 years, will be investigated. Other approaches to enzymatic based energy sources will also be examined. Finally, materials technologies will also be employed in novel approaches for obtaining and purifying water in the field as well as air purification.



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(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 (1000 Whrs/kg); 2) a 3 day land warrior mission (2000 Whrs/kg); and 3) a 10 day special operation forces mission (3000 Whrs/kg).
- Develop and demonstrate enabling direct thermal to electric conversion technologies with potential for high (> 20%) conversion efficiencies and high (> 1 W/cm<sup>2</sup>) 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.
- Demonstrate efficient, low cost, 200 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 (water-from-air, combusted hydrocarbons, and urine) for the individual warfighter and small groups of soldiers.
- Develop and demonstrate novel technologies for low-power purification of any brackish or salty brine solution.
- Demonstrate materials and components for a hybrid superconducting power system for a terrestrial (>5 MW) application that has high efficiency and reliability and the potential for significantly reduced size (10x) and weight (5x).
- Develop novel rectifying antenna approaches that will allow efficient beaming of power between spacecraft.
- Demonstrate processes that can convert military waste to usable military logistic fuels.
- Increase the power density of small electric motors and hydrocarbon powered engines by a factor of more than 10 times.
- 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 fuel cell powered prototype surveillance platforms capable of maintaining a sustained presence.

|                                  | FY 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Strategic Material Manufacturing | 3.400   | 0.000   | 0.000   |

(U) Program Accomplishments:

- Continued to develop new manufacturing approaches for cutting tools and other ceramics used for Defense applications.

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|                       | FY 2003 | FY 2004 | FY 2005 |
|-----------------------|---------|---------|---------|
| Heat Actuated Coolers | 1.000   | 1.200   | 0.000   |

- (U) Program Plans:
- Continue 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 2003 | FY 2004 | FY 2005 |
|-----------------------|---------|---------|---------|
| Friction Stir Welding | 1.000   | 1.200   | 0.000   |

- (U) Program Plans:
- Continue to investigate the applicability of using Friction Stir Welding to join amorphous alloys without recrystallization.

|                                       | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------------|---------|---------|---------|
| Advanced Materials Research Institute | 0.000   | 1.800   | 0.000   |

- (U) Program Plans:
- Develop nano devices fabricated by bottoms-up fabrication techniques that will form the basis for novel sensors as well as have the potential for information storage.

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|                              | FY 2003 | FY 2004 | FY 2005 |
|------------------------------|---------|---------|---------|
| Materials Science Technology | 0.000   | 0.750   | 0.000   |

- (U) Program Plans:
  - Continue development of a training program for advanced composite materials that integrates university and community college programs with industry needs to develop a comprehensive curriculum to meet the growing demand for a trained workforce and identify best practices for the industry.
- (U) **Other Program Funding Summary Cost:**
  - Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Microelectronic Device Technologies, MPT-02                                  | 135.911 | 169.709 | 190.881  | 205.018 | 226.203 | 233.922               | 239.076 |

(U) **Mission Description:**

(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 Microelectronics Device Technologies Project supports the continued advancement of these technologies through the development of performance driven advanced capabilities, exceeding that available through commercial sources, in electronic, optoelectronic and MEMS devices, semiconductor device design and fabrication techniques, and new materials and material structures for device applications. A particular focus for this work is the exploitation of chip-scale heterogeneous integration technologies that permit the optimization of device and integrated module performance.

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

|                                   |         |         |         |
|-----------------------------------|---------|---------|---------|
|                                   | FY 2003 | FY 2004 | FY 2005 |
| Adaptive Focal Plan Arrays (AFPA) | 3.556   | 6.775   | 7.503   |

(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).

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- (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.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Vertically Interconnected Sensor Arrays (VISA) | 11.356  | 9.628   | 8.900   |

(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.

- (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.

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|                                | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------|---------|---------|---------|
| Imaging Coherent Optical Radar | 0.000   | 9.000   | 11.000  |

(U) This program, utilizing extremely high speed imaging nanotechnology, will develop new coherent optical radar cameras, up to GHz sampling rate, for imaging/non-imaging high sensitivity vibrometry, Doppler and intensity measurements, and achieve extremely fast high performance imaging in small, low power, reduced thermal load, producible devices for insertion throughout the military community. The technology will do what radar does, but with an optical carrier and optical resolution.

(U) Program Plans:

- Obtain vibrational (acoustic) spectral images of targets of interest.
- Detect relative motion of objects and materials (moving target identification-MTI).
- Develop coherent heterodyne local oscillator concepts and coherent single photon counting concepts.
- Demonstrate nanofabrication techniques for realizing broadband coherent optical sources with tailored spectral output for imaging, communication, targeting and countermeasure applications.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| 3-D Microelectromagnetic RF systems (3-D MERFS) | 0.000   | 3.480   | 4.020   |

(U) The 3-D Microelectromagnetic RF systems (3-D MERFS) program, formerly Highly Integrated Millimeter Wave (MMW) Electronically Scanned Array (ESA), will investigate the possibility of making 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

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for point-to-point communications, sensors for smart munitions, robotics and small remotely piloted vehicles. This program will build upon technology which was developed under the Vertically Interconnected Sensor Array.

- (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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Analog Optical Signal Processing (AOSP) | 12.557  | 11.538  | 8.500   |

(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.

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- Determine interface requirements.
- Evaluate the suitability of the new components for use in prototype modules.
- Down-select to the most promising approaches and begin prototype module assembly.
- Construct testbeds capable of fully characterizing the photonic-based RF signal processing components.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Advanced Precision Optical Oscillator (APROPOS) | 0.000   | 3.929   | 4.904   |

(U) The APROPOS program, formerly titled Precision Optical Oscillators, 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.



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|                           | FY 2003 | FY 2004 | FY 2005 |
|---------------------------|---------|---------|---------|
| Advanced Digital Receiver | 0.000   | 0.000   | 2.800   |

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

(U) Program Plans:

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

|                         | FY 2003 | FY 2004 | FY 2005 |
|-------------------------|---------|---------|---------|
| Chip Scale Atomic Clock | 15.225  | 15.930  | 15.840  |

(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.

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- (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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Technology Efficient, Agile Mixed Signal Microsystem (TEAM) | 15.036  | 14.362  | 14.712  |

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

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

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST) | 26.104  | 23.800  | 16.000  |

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

(U) Program Plans:

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

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|                 | FY 2003 | FY 2004 | FY 2005 |
|-----------------|---------|---------|---------|
| Clockless Logic | 0.000   | 4.367   | 5.643   |

(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.
- 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 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Carbon Nanotube Induced Reactions | 0.000   | 0.000   | 3.308   |

(U) The Carbon Nanotube Induced Reactions program will develop a technology base for making use of the nanotube-microwave interactions that allows (1) intense heat release at a rapid rate and (2) microwave absorption with “radar-transparent” applications. It is envisioned that interactions between carbon nanotubes and electromagnetic radiation can be exploited to provide (1) rapid energy release at several times or more of the input energy and (2) magnetic radar absorbing material formed by polymers loaded with carbon nanotubes.

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- (U) Program Plans:
- Develop technologies to understand the cascade of the fundamental physical and chemical processes that arise during microwave irradiation of single wall carbon nanotubes (SWNTs) under conditions which lead to intense light bursts and high thermal energy output to the surroundings.
  - Identify contributing underlying mechanisms, whatever their detailed nature, e.g., nuclear, chemical or other processes, through time resolved spectroscopies and particle emission measurements combined with detailed changes in the structural and chemical nature of the SWNTs induced by irradiation.
  - Investigate novel microwave absorbing materials based on carbon nanotube-loaded polymers.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Design Tools for 3-Dimensional Electronic Circuit Integration | 0.000   | 9.000   | 10.500  |

(U) This program will develop a new generation of 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 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.

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|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Chip-to-Chip Optical Interconnects | 0.000   | 3.086   | 7.000   |

(U) Continuing advances in integrated circuits technology are expected to push the clock rates of 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, the proposed program will develop optical technology for implementing chip-to chip interconnects at the board and back plane level.

- (U) Program Plans:
- 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.
  - High speed (faster than 10 GBps), low power (less than 50 mW) optical transmitter/receivers.
  - Integration of optical transmitters/receivers and optical data paths with electronic packaging and manufacturing approaches.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Multiple Optical Non-redundant Aperture Generalized Sensors (MONTAGE) | 0.000   | 0.000   | 4.367   |

(U) The MONTAGE program aims to 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 obtain from 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.

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(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.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| High Frequency Wide Band Gap Semiconductor Electronics Technology | 25.279  | 25.000  | 22.297  |

(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.

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- 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/cm<sup>2</sup> and resistivity 10<sup>6</sup> 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/cm<sup>2</sup> and resistivity 10<sup>7</sup> 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/cm<sup>2</sup> power density in high power devices.
- Optimize wide band gap semiconductor materials to achieve 100 mm substrates with less than 10 micropipe/cm<sup>2</sup> and resistivity greater than 10<sup>7</sup> ohms-cm at room temperature.
- Demonstrate fabrication processes for robust microwave and mm-wave devices with RF yields greater than 70 percent.
- Demonstrate thermal management concepts to sustain more than 1KW/cm<sup>2</sup> power density in high power devices.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| High Power Wide Band Gap Semiconductor Electronics Technology | 11.805  | 12.314  | 14.000  |

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

(U) Program Plans:

- Develop low defect conducting Silicon Carbide (SiC) substrate consistent with yielding 1 cm<sup>2</sup> devices.
- Develop lightly doped, thick (more than 100 micron) SiC epitaxy with low defects to enable 10 kV class power devices.



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- Develop low on-state resistance SiC diodes capable of blocking 10 kV.
- Demonstrate SiC wafer and thick epitaxy with less than 1.5 catastrophic defects per cm<sup>2</sup> 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 operation.
- Develop integrated power control logic compatible with high temperature and power SiC power devices.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Robust Integrated Power Electronics (RIPE) | 0.000   | 11.000  | 10.000  |

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

(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.

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- 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 2003 | FY 2004 | FY 2005 |
|-----------|---------|---------|---------|
| UltraBeam | 0.000   | 0.000   | 3.087   |

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

(U) Program Plans:

- Validate the scientific feasibility of the conversion and propagation processes.
- Demonstrate a working laboratory model involving higher beam energies and shorter pulse durations.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Submillimeter Wave Imaging FPA Technology (SWIFT) | 0.000   | 0.000   | 5.000   |

(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 will build upon 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.

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|                            | FY 2003 | FY 2004 | FY 2005 |
|----------------------------|---------|---------|---------|
| Direct Analog To Target ID | 0.000   | 0.000   | 4.000   |

(U) This program will explore, develop, and demonstrate radical departures from current methods of analog-to-digital (A/D) and digital-to-analog D/A conversion based on uniformly sampled and quantized approximations of analog signals, toward new approaches for extracting higher-level digital information directly from analog signals. The program will pursue thorough and critical application of “off the beaten track” ideas in converters, including signal-class adaptive multiplexing and encoding in analog layer for reduced dynamic range requirements, biologically inspired signal processing and noise reduction, and novel mathematical approaches for discriminating information from interference.

(U) Program Plans:

- Develop broadly applicable methodologies for exploiting novel encoding strategies, closed loop adaptive equalization, integration of sensing and processing, and application-specific knowledge in order to provide revolutionary advances in information conversion.
- Explore novel architectures leveraging intelligent pre-processing based upon space, time, and mathematical transformations of analog measurements and employing cooperative integration of analog and digital processing to obtain required system level performance.
- Work with new classes of quantization devices based on novel “error correcting” representations of numbers, such as beta encoders, phase encoders, geometric invariants.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Terascale Integration for Scalable Mixed Signal Microsystems | 0.000   | 0.000   | 4.000   |

(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.

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- (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 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Radio Isotope Micropower Sources | 0.000   | 0.000   | 3.500   |

(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 nuclear battery approaches that harness MEMS technology to safely and efficiently convert nuclear energy to either electrical or mechanical power while avoiding lifetime-limiting damage to the power converter caused by highly energetic particles (e.g., such as often seen in previous semiconductor approaches to energy conversion). The goal is to provide electrical power to macro-scale systems such as munitions, unattended sensors, and weapon systems, RF ID tags, and other applications requiring relatively low (up to tens of milliwatts) average power.

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

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Photonic Wavelength and Spatial Signal Processing (Photonic WASSP) | 7.026   | 0.000   | 0.000   |

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

(U) Program Accomplishments:

- Developed micro-machined optical elements for spectral bands 300 to 500 nm and 3 to 15 microns.
- Initiated integration of the passive elements into beam conditioners.
- Demonstrated integration with packaging module.
- Demonstrated module in a testbed for bio-chemical sensing and spectral imaging.
- Transitioned technology to DoD hyperspectral/imaging programs and systems.

|                              | FY 2003 | FY 2004 | FY 2005 |
|------------------------------|---------|---------|---------|
| Fabrication of 3D Structures | 2.277   | 2.000   | 0.000   |

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

(U) Program Plans:

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

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Center for Optoelectronics and Optical Communications | 4.743   | 2.500   | 0.000   |

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

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

|                                   | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Nano Photonic Systems Fabrication | 0.947   | 1.000   | 0.000   |

- (U) Program Plans:
- Prepare new materials for applications in lasers and nano-inspired optics.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Integrated Nano and Micro-manufacturing | 0.000   | 1.000   | 0.000   |

- (U) Program Plans:
- Initiate development of advanced nano and micro-manufacturing technologies.

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

- Not Applicable.

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Cryogenic Electronics MPT-06   | 6.895   | 4.911   | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |

(U) **Mission Description:**

(U) Thin-film electromagnetic materials have reached a stage of development where specific applications can be identified in electronic devices and circuitry for military systems. Films may be deposited and patterned to form electromagnetic components in ways that are similar to, and compatible with, the processes of conventional semiconductor manufacturing. Such electromagnetic components, as well as complementary metal oxide semiconductors (CMOS), work best at lower temperatures, so that cryogenic packaging generally will be required for optimum performance. Thin-film high temperature superconducting (HTS) components packaged with cryogenic devices are being applied to radars, electronic warfare suites, and communications systems to enhance performance by more than an order of magnitude while reducing size and power requirements. Particular demonstrations include detection and geolocation of targets of high interest based upon low-level characteristic emissions and communications receivers with greater immunity to interference. Highly dependable and inexpensive cryocoolers are also being developed for these applications. These latter development efforts include the exploration of techniques to improve the performance of solid-state thermoelectric materials and devices in applications ranging from communications to power generation. This project draws to a close at the end of FY 2004, a reflection of the maturity level that DARPA has obtained in cryogenic electronic technology development and sub system insertion. Any further integration of this technology into weapon/sensor systems will be budgeted in the respective platform's PE and projects.

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

|                                     |         |         |         |
|-------------------------------------|---------|---------|---------|
|                                     | FY 2003 | FY 2004 | FY 2005 |
| Totally Agile Sensor Systems (TASS) | 4.149   | 0.000   | 0.000   |

(U) The sensitivity of a standard radio receiver for the detection of small signals in an interfering background can be enhanced up to 10X, by the insertion of a high temperature super conducting (HTS) filter at the input of the receiver. Such ultra-sensitive receivers, mounted on military aircraft, ships and ground installations, have proven to be highly effective for SIGINT and COMINT missions. The Totally Agile Sensor Systems (TASS) program has demonstrated frequency tunability of HTS filters up to 30% of base frequency, thereby providing greater agility to cover the



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frequency spectrum. The final phases of the TASS program were directed toward enhancing performance even further in terms of sensitivity and selectivity, by narrowing the bandwidth of the HTS filter by 10-100X, while maintaining tunability. Such capability has vastly improve overhead SIGINT collection in a spectrally-crowded environment.

(U) Program Accomplishments:

- Fabricated novel HTS filters with ultra-high quality factor (Q) and 0.1% bandwidth.
- Incorporated agile front-end pre-selector modules utilizing tunable high-Q HTS filters within standard receivers.
- Demonstrated totally agile sensor systems with ten times SIGINT and COMINT capability.
- Adapted ultra-high Q and tunability for demonstration in a receiver console, with features for sweep rate and filter reconfiguration.
- Transitioned capability for 30 percent tunability to RC-135 aircraft demonstration.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Rapid Identification and Targeting (RAPIT) | 2.746   | 2.411   | 0.000   |

(U) The goal of the RAPIT program is to develop a method of detection, identification and location of hidden threat forces which are not emitting radiation and are not discernable by present technical means. In the context of a network centric model, utilizing lightweight and lightly-armored systems, a probable threat is a foot soldier (dismount) with a rocket propelled grenade or similar weapon. Since it is likely that he will be carrying a radio or other communications gear, it is possible to detect and identify the radio by (1) its emission in standby mode (leakage), or (2) an induced nonlinear RF return if appropriately stimulated (stimulated leakage), even when the radio is unpowered. Both these techniques were originally demonstrated within the DARPA TASS program utilizing RF receivers with tunable HTS front-end filters. Only tunable HTS front-end filters have the necessary sensitivity and selectivity for low-level RF signals detection. Detection ranges of over 2 Km are possible in the near-term. The RAPIT technique will be fully developed and quantified for all likely threats, and a targeting system will be assembled.

(U) Program Plans:

- Measure radio frequency emission characteristics of generic components, active and passive modes, on bench top and in anechoic chambers.
- Determine range projections for target detection, based upon initial measurements and likely scenarios.
- Evaluate clutter, intermodulation distortion and propagation effects on targeting.

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- Demonstrate detection of specific targets from an airborne platform.
- Evaluate detection and geolocation of multiple targets and target classes.

|                                      | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| Cryo-power for the All Electric Ship | 0.000   | 2.500   | 0.000   |

(U) This effort will leverage the success of the Cryogenics Electronics project and apply it to the development of a test bed for cryo-electronic components for power systems, particularly those of interest to the Navy for their all-electric ship program.

(U) Program Plans:

- Develop and test cryogenic semiconductor switching elements, cryogenic cables and superconducting passive elements including tape, inductors and transformers.

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

- Not Applicable.

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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA2 Applied Research |         |         | R-1 ITEM NOMENCLATURE<br>Materials and Electronics Technology<br>PE 0602712E, Project MPT-08 |         |         |                       |         |
| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Beyond Silicon MPT-08  | 80.152  | 83.976  | 61.827   | 34.570  | 28.657  | 16.000                | 16.000  |

(U) **Mission Description:**

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

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

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

|  |         |         |         |
|--|---------|---------|---------|
|  | FY 2003 | FY 2004 | FY 2005 |
| Quantum Information Science and Technology (QuIST) | 20.693  | 27.268  | 23.980  |

(U) The Quantum Information Science and Technology (QuIST) program will explore all facets of the research necessary to create a new technology based on quantum information science. Research in this area has the ultimate goal of demonstrating the potentially significant advantages of quantum mechanical effects in communication and computing. Technical challenges include loss of information due to quantum

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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 a focus effort to build and demonstrate a scalable quantum information processor that will address issues such as architecture and manufacturability.

(U) Program Plans:

- Determine quantum architecture and design solutions for problems such as graph isomorphism, imaging, and signal processing.
- Investigate alternative protocols for secure quantum communication, quantum complexity, and control.
- Investigate the use of quantum information in metrology.
- Demonstrate improved single and entangled photon sources and detectors.
- Investigate alternative designs, architectures and devices for quantum communication, computation, and memory; demonstrate low overhead, fault tolerant solid state quantum bit (qubit) memory and gates with at least two entangled qubits.
- Employ scalable qubit architectures to demonstrate an application of interest to the DoD (e.g., quantum repeater).
- Refine and integrate quantum communications systems into existing DoD and intelligence community networks.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Polymorphous Computing Architecture (PCA) | 15.012  | 16.992  | 14.074  |

(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, and reduce payload adaptation, optimization, and verification from years to days to minutes. Current DoD embedded computing systems can be characterized as static in nature, relying on hardware-driven, heterogeneous point-solutions that represent static architectures and software optimizations. The program breaks the current development approach of hardware first and software last by moving beyond conventional silicon to flexible polymorphous computing systems. The key efforts of this revolutionary step forward in embedded computing systems are: 1) define critical reactive computing requirements and critical micro-architectural features; 2) explore, develop and prototype reactive polymorphous computing concepts; 3) explore,

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develop and prototype multi-dimensional verification and validation techniques for dynamic reactive missions; and 4) provide early experimental testbeds and prototype polymorphous computing systems. The result will be an embedded computing processing capability that will be mission and technology invariant yet highly optimizable for each new mission instantiation, thus providing for tactical and strategic mission tempo opportunities as well as technical upgradeability over the life of the computing system. Based on an average of four major upgrades over a 30 year period, significant saving of up to 45 percent in development and deployment costs may now be achieved over the life of a typical DoD embedded computing system by applying this technology. 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:

- Characterize and perform functional decomposition of pivotal reactive system algorithms and computing functions.
- 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.
- Develop line-of-sight and collision computations using GPU.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Antimonide Based Compound Semiconductors (ABCS) | 9.870   | 9.346   | 0.000   |

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

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(U) Program Plans:

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

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD) | 12.056  | 8.987   | 0.000   |

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

(U) Program Plans:

- Develop Model Order Reduction methods (for analog and photonic devices) to enable the creation of behavioral models.
- Develop and demonstrate top-down design capabilities for analog, mixed signal and mixed electronic/photonic systems that match the efficiency currently achieved with digital designs.
- Develop fast solvers for analog and photonic devices; perform non-linear model order reduction, develop extraction tools, synthesis and layout capabilities for mixed signal and mixed electronic/photonic circuits, develop interfaces with existing digital tools to enable co-simulation.
- Demonstrate the tools for designing and prototyping selected mixed electronic/photonic circuits and mixed signal systems (e.g., Analog-to-Digital Converters) for military applications.

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- Develop 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 2003 | FY 2004 | FY 2005 |
|-------------|---------|---------|---------|
| Moletronics | 22.521  | 11.330  | 0.000   |

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

(U) Program Plans:

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



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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Applications of Molecular Electronics (MoleApps) (formerly Molecular Computing) | 0.000   | 10.053  | 10.020  |

(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 a 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.

|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Focused Quantum Systems (FoQuS) | 0.000   | 0.000   | 13.753  |

(U) The FoQuS program will develop a path towards an advanced quantum factoring machine drawing on the fundamental understanding and foundations developed under the QuIST program 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 processor in a decade rather than a score of years, as projected by the current roadmap.

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

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| COST (In Millions)   | FY 2003 | FY 2004 | FY 2005 | FY 2006  | FY 2007 | FY 2008               | FY 2009 |
| Biologically Based Materials and Devices MPT-09                              | 65.321  | 77.997  | 89.858  | 96.402   | 82.169  | 86.093                | 78.017  |

(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 development of multifunctional transducers based on biological membranes, the application of magnetic materials in biological applications, and the development of manufacturing tools that use biological components and processes for materials synthesis.

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

|                                      |         |         |         |
|--------------------------------------|---------|---------|---------|
|                                      | FY 2003 | FY 2004 | FY 2005 |
| Bioinspired and Bioderived Materials | 30.728  | 35.297  | 38.000  |

(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 biomimetic sensory prototypes that collect electromagnetic olfactory and visual inputs.
- Define new, malleable materials for coordinated appendage function in land, water, and air platforms 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.
- Demonstrate a material system based on bio-inspired optics technology that can produce a reversible change in the index of refraction of 1.0 point over a bandwidth of at least 50 nanometers with 95% or better transmittance allowing a re-configurable optical system that is capable of changing between wide angle (120 degrees) and narrow field of view within a frame rate.
- Develop bio-inspired optical components and filters based on novel materials chemistry, and directed self-assembly principles that guide unique hierarchical structure.
- Determine and quantify the mechanism of motor function, motor performance, and efficiency for several types of biomolecular motors through computational models and experimental measurements.
- Isolate, modify, and integrate biomolecular motors with synthetic/inorganic materials to demonstrate devices with unique energy conversion capabilities and potential DoD utility.
- 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, 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.

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|                       | FY 2003 | FY 2004 | FY 2005 |
|-----------------------|---------|---------|---------|
| Biochemical Materials | 30.593  | 24.000  | 32.000  |

(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, the modeling of the biochemical behavior of organs and tissues 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.
- Develop new approaches for increasing the availability of blood products.
- Develop self-care medical technology to enable the warfighter in the battlefield to accelerate wound healing, internal clotting and pain relief to increase a soldier's survivability on the battlefield.
- Develop an understanding of the biochemical and physiological causes of decreased cognitive performance during sleep deprivation through studying animal model systems, synaptic function, and transcranial magnetic stimulation (TMS).
- Demonstrate and validate approaches to develop biomaterials and other concepts that extend the cognitive performance capabilities of warfighters during extended periods of sleep deprivation and stress.
- Develop methods 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 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.

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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.
- Define and demonstrate new operating room technologies for the battlefield.

|                                   | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Bio-Fabrication (Formerly REMEDE) | 0.000   | 7.000   | 9.000   |

(U) The Bio-Fabrication (B-FAB) program will demonstrate the feasibility of using biological processes and artificial membranes as a new nanofabrication toolset to synthesize and manufacture chemicals, materials, and devices of high value to the DoD. Specific targets for demonstration within this program include scalable technologies for electronic materials and devices (ultra-low-k dielectrics; GaN-InGaN-AlGaN and InP-GaP-AlP-AlInGaP materials, 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 developing 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 these materials at the scale of interest (e.g., single crystal GaN, 1 micron by 1 micron by 100 nm).
- Develop computational, fabrication, and process control tools for the design, manipulation, and optimization of the biocatalytic, enzymatic, bio-pathway, or organisms with the target synthetic properties necessary for the fine-scale manipulation of biosynthetic fabrication.
- Develop and demonstrate the capability to produce bio-fabricated materials with chemically and/or spatially modulated properties, possibly including controlled doping (n-type, p-type), stacked nano-layers, quantum dots, or 3-D articulated structures in a candidate electronic, optical, or mechanical device material.
- Demonstrate the integrability of biosynthetic fabrication processes with current fabrication and/or micro-fabrication toolsets.

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- Design, develop, and demonstrate integrated biosynthetic fabricated electronic, optical, or mechanical devices with improved or otherwise unattainable performance or cost characteristics.
- Develop device architectures capable of accelerating protein identification by over two orders of magnitude in time reduction.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Bio-Magnetic Interfacing Concepts (BioMagnetICs) | 4.000   | 10.000  | 10.858  |

(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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| University of Florida Biosensor/Biomotive Nano Technology | 0.000   | 1.700   | 0.000   |

(U) Convert innovative 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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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |         |         | R-1 ITEM NOMENCLATURE<br>Advanced Aerospace Systems<br>PE 0603285E, R-1 #32 |         |         |                       |         |
| COST (In Millions)  | FY 2003 | FY2004  | FY2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost   | 242.095 | 315.941 | 361.067   | 381.179 | 423.281 | 423.120               | 419.014 |
| Advanced Aerospace Systems ASP-01   | 130.527 | 114.357 | 111.847   | 147.573 | 161.512 | 126.190               | 92.000  |
| Space Programs and Technology ASP-02  | 111.568 | 201.584 | 249.220   | 233.606 | 261.769 | 296.930               | 327.014 |

(U) **Mission Description:**

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

(U) A number of aeronautical programs are funded in the Advanced Aerospace Systems project. The A160 Hummingbird Warrior program exploits a hingeless, rigid, rotor concept operating at the optimum rotational speed to produce a vertical take-off and landing unmanned air vehicle with very low disk loading and rotor tip speeds resulting in an efficient low power lo iter and high endurance system. The Canard Rotor/Wing aircraft program focuses on high-speed, rapid response vertical take-off and landing designs with improved range and stealth capabilities.

(U) Also funded within the Advanced Aerospace Systems project are several unmanned combat air vehicles. The Unmanned Combat Air Vehicle program focused on risk reduction and “Concept of Operation” evaluation. The Naval Unmanned Combat Air Vehicle program validated the technical feasibility for a naval unmanned combat air system to effectively and affordably perform naval Suppression of Enemy Air Defense/Strike/Surveillance missions. The results of these programs led to the formation of the DARPA/Air Force/Navy Joint-Unmanned Combat Air System. The goal of the Unmanned Combat Armed Rotorcraft program is to design, develop, integrate and demonstrate the enabling technologies and system capabilities required to perform mobile strike concept of operations. The Walrus program, an outgrowth of the Long Endurance Hydrogen Powered Unmanned Air Vehicle and the Unmanned Tilt Rotor programs, will develop and construct an Advanced Technology Demonstration Air Vehicle with comparable C-130 airlift capability.

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(U) The Space Programs and Technology Project is developing a space force structure that will be robust against attack. In addition to the ability to detect and characterize potential attacks, robustness against attack is provided by proliferation of assets, ready access to space and a flexible infrastructure for maintaining the capabilities of on-orbit assets. Ready access to space allows the delivery of defensive systems and replenishment supplies to orbit. An infrastructure to service the mission spacecraft allows defensive actions to be taken without limiting mission lifetime. The Orbital Express Space Operations Architecture program will develop and demonstrate autonomous techniques for on-orbit refueling and reconfiguration of satellites that could support a broad range of future U.S. national security and commercial space programs. The Space Surveillance Telescope program will develop and demonstrate an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability. The Innovative Space-Based Radar Antenna Technology program addresses the technical and economic feasibility of developing space-based radar antennas necessary for tactical-grade ground moving target indicator performance from space. Deep view is developing a high-resolution radar imaging capability to characterize objects in the earth's orbit. The Responsive Access, Small Cargo, and Affordable Launch program will develop and demonstrate the capability to launch small satellites and commodity payloads into low-earth orbit. The High Frequency Active Auroral Research Project (HAARP) will develop new experimental research capabilities to exploit emerging ionosphere and radio science technologies related to advanced defense applications.

(U) An outgrowth of the space vehicle technologies and Hypersonics (TT-03) initiatives, the HyperSoar program will develop a dual use capability of an intercontinental global delivery vehicle and a first stage reusable space access vehicle. The Rapid On-orbit Anomaly Surveillance and Tracking program seeks to provide a space-based capability to detect and track on-orbit objects with rapid revisit rates and low latencies. The Tactically Responsive Satellites program will develop a spacecraft to provide high resolution imaging day or night using extremely lightweight optics and a compact design capable of being launched on a Pegasus air launch booster.

| <b>(U) <u>Program Change Summary:</u> (In Millions)</b> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|---|-----------------------|-----------------------|----------------------|
| Previous President's Budget                             | 235.300               | 323.730               | 340.567              |
| Current President's Budget                              | 242.095               | 315.941               | 361.067              |
| Total Adjustments                                       | 6.795                 | -7.789                | 20.500               |

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|                                  | <b>FY 2003</b> | <b>FY 2004</b> |
|----------------------------------|----------------|----------------|
| Congressional program reductions | 0.000          | -9.289         |
| Congressional increases          | 0.000          | 1.500          |
| Reprogrammings                   | 7.056          | 0.000          |
| SBIR/STTR transfer               | -0.261         | 0.000          |

(U) **Change Summary Explanation:**

|         |   |
|---------|---|
| FY 2003 | Increase reflects program repricing and SBIR transfer.  |
| FY 2004 | Decrease reflects congressional reductions to space and hypersonic programs and undistributed reductions offset by an add for suborbital space launch operations.         |
| FY 2005 | Increase reflects additional funding for Walrus, Orbital Express, and several new space initiatives offset by repricing of several other aeronautics technology programs. |

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Advanced Aerospace Systems ASP-01   | 130.527 | 114.357 | 111.847  | 147.573 | 161.512 | 126.190               | 92.000  |

(U) **Mission Description:**

(U) ‘The Advanced Aerospace Systems project addresses high payoff opportunities to dramatically reduce costs associated with advanced aeronautical systems and provide revolutionary new system capabilities for satisfying current and projected military mission requirements. Research and development of integrated system concepts, as well as enabling vehicle subsystems will be conducted. Studies conducted under this project include examination and evaluation of emerging aerospace threats, technologies, concepts, and applications for missiles, munitions, and vehicle systems.

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

|  |         |         |         |
|--|---------|---------|---------|
|  | FY 2003 | FY 2004 | FY 2005 |
| Advanced Air Vehicle: A160 Hummingbird Warrior | 13.645  | 9.500   | 9.000   |

(U) The A160 Hummingbird Warrior program will exploit a hingeless, rigid rotor concept operating at the optimum rotational speed to produce a vertical take-off and landing (VTOL) unmanned air vehicle (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 (24-48 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. It is being developed as a component of the DARPA/Army Future Combat Systems (FCS) Program. In addition, this program will evaluate application of the optimum speed rotor concept to other systems including heavy lift and tilt rotor capabilities. The program will also conduct development tests of heavy fuel engine technology and coordinate with other DARPA programs developing highly efficient heavy fuel engine technologies to further advance current range and endurance projections as well as improve operational reliability and

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logistics compatibility. In FY 2003, this program received additional funding from Congress ( \$1.614 million) to repair and upgrade Air Vehicle #1.

(U) Program Plans:

- Fabricate and test low vibration rotor modifications.
- Continue ground and flight test of A160 vehicles.
- Develop concept design of an unmanned ground vehicle deployment system for A160 vehicle.
- 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 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Unmanned Combat Air Vehicle (UCAV) | 59.909  | 0.000   | 0.000   |

(U) DARPA and the Air Force jointly developed and funded the Unmanned Combat Air Vehicle (UCAV) System Demonstration Program (SDP) to demonstrate the technical feasibility, military utility, and operational value of a UCAV system to effectively and affordably prosecute lethal and non-lethal Suppression of Enemy Air Defense (SEAD) and strike missions within the emerging global command and control architecture. The overall purpose of the UCAV SDP was to design, develop, integrate, and demonstrate the critical technologies, processes, and system attributes pertinent to an operational UCAV system. The UCAV SDP is currently executing flight demonstrations with the X-45A air vehicle and is in the design phase for low observable robust prototypes. The results of this research led to the formation of the DARPA/Air Force/Navy Joint Unmanned Combat Air System.

(U) Program Accomplishments:

- Developed and demonstrated core UCAV functionality.
- Initiated design of next iteration low observable (LO) robust prototypes.
- Delivered two robust demonstration air vehicles.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Naval Unmanned Combat Air Vehicle (UCAV-N) | 21.527  | 0.000   | 0.000   |

(U) The Naval Unmanned Combat Air Vehicle (UCAV-N) science and technology program validated the technical feasibility of naval unmanned combat air system effectively and affordably performing naval Suppression of Enemy Air Defense (SEAD)/Strike/Surveillance missions within the emerging global command and control architecture. This initiative investigated and validated the critical technologies, processes and system attributes associated with the development of a UCAV-N system. Analysis of the potential capability enhancements that would be realized by legacy force carrier air wings through the introduction of 12 to 16 carrier-capable, multi-mission Strike, SEAD and Surveillance unmanned combat aircraft was investigated. The program also emphasized a low life cycle cost combat effective design. The results of the program led to the formation of the DARPA/Air Force/Navy Joint-Unmanned Combat Air System.

- (U) Program Accomplishments:
- Conducted demonstrations of technologies, processes, and systems attributes to demonstrate the feasibility of a low observable UCAV-N system capable of routine operation from aircraft carriers.
  - Initiated detailed design of a demonstrator aircraft.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Joint Unmanned Combat Air System (J-UCAS) | 0.000   | 41.385  | 0.000   |

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

(U) The J-UCAS program combines 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



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X-45A technology demonstrator, as well as the development of the X-47A demonstrator, will reduce the risk of the system being developed for the operational assessment. The J-UCAS concept incorporates the Boeing X-45C/CN and Northrop Grumman X-47B air vehicles, together with a common architecture and subsystems (e.g. sensors, communications, and command & control software). These common system elements will maximize system flexibility and operational versatility, while reducing overall costs and maintaining schedule toward an Early Operational Assessment planned for the FY08-09 timeframe.

(U) The J-UCAS Office integrates 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 and subsequent fiscal years has been consolidated in two new program elements (PE 0603400D8Z and PE 0604400D8Z).

(U) Program Plans:

- Continue demonstrations with the X-45A to validate multi-vehicle coordinated operations and onboard intelligent software capable of dynamic retasking/replanning and distributed control beyond line of sight, with a robust contingency management system.
- Complete detailed design and initiate construction of the X-45C/CN and X-47B J-UCAS demonstrator aircraft.
- Initiate development of common system elements, including a common architecture and subsystems, to reduce risk and maintain schedule.
- Support development of Joint Service operational requirements and planning for the Early Operational Assessment phase of the program.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Unmanned Combat Armed Rotorcraft (UCAR) | 24.755  | 37.432  | 55.404  |

(U) The goal of the Unmanned Combat Armed Rotorcraft (UCAR) program is to design, develop, integrate and demonstrate the enabling technologies and system capabilities required to perform armed reconnaissance and attack missions within the Army's Objective Force system-of-systems environment. The enabling technologies are survivability, autonomous operations, command and control, and targeting/weapons delivery. A highly survivable UCAR system will prosecute enemy high value targets with relative impunity without placing a pilot in harm's way. UCAR's autonomous capabilities will enable effective teaming with manned systems and will eliminate the requirement for a dedicated ground control

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station. The UCAR capabilities will provide the Objective Force with the mobility, responsiveness, lethality, survivability, and sustainability required to ensure mission success. Specific objectives of the UCAR program include: development and demonstration of an effective, low total ownership cost design for the system; an air and ground-based command and control architecture for UCAR operations that does not require a dedicated ground control station; autonomous multi-ship cooperation and collaboration; autonomous low altitude flight; and system survivability.

(U) Program Plans:

- Continue system trades, effectiveness, and affordability analyses through modeling and simulation.
- Develop sufficient system concept fidelity to validate program goals and objectives.
- Complete the preliminary design and the Preliminary Design Review of the Demonstration System.
- Select one team for Phase III, System Demonstration.
- Initiate detailed design of the Demonstration System.
- Complete the Critical Design Review of the Demonstration System.
- Initiate fabrication of two UCAR Demonstrators.
- Perform component risk reduction demonstrations.

|                           | FY 2003 | FY 2004 | FY 2005 |
|---------------------------|---------|---------|---------|
| Quiet Supersonic Platform | 3.835   | 4.370   | 7.000   |

(U) The Quiet Supersonic Platform (QSP) program is directed towards development and validation of critical technology for long-range advanced supersonic aircraft with substantially reduced sonic boom, 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. The objective is to develop and demonstrate these technologies in a series of tests to validate performance. Work performed this past fiscal year included 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

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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.

(U) Program Plans:

- Conduct high fidelity wind tunnel test of large-scale semi span wing design to simulate actual supersonic flight conditions.
- Initiate preliminary design of laminar flow control technology integrated into flight test vehicle.
- Perform computational fluid dynamics calculations and conduct low and high speed wind tunnel tests of flight test vehicle to assess safety of flight.
- Conduct flight-testing to validate low drag technology in real flight environment.

|                         | FY 2003 | FY 2004 | FY 2005 |
|-------------------------|---------|---------|---------|
| Canard Rotor/Wing (CRW) | 3.233   | 11.763  | 14.542  |

(U) The Army, Navy, Air Force, and Marine Corps have a need for affordable, survivable, vertical take-off and landing (VTOL) air vehicles to support dispersed units. Canard Rotor/Wing (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 to design, development and demonstration of more operationally representative vehicles including manned aircraft.

(U) Program Plans:

- Conduct demonstrator flight tests.
- Begin design and development of follow-on manned and unmanned vehicles.

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|                                      | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| Cormorant Unmanned Air Vehicle (UAV) | 0.000   | 0.000   | 2.984   |

(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 Combo ship (LCS) and SSGN.

- (U) Program Plans:
- Initiate feasibility studies; conduct modeling and simulation vehicle behaviors in the air/sea interface.
  - Explore novel composite materials.

|                           | FY 2003 | FY 2004 | FY 2005 |
|---------------------------|---------|---------|---------|
| Heavy Fuel Enginefor A160 | 2.144   | 4.426   | 4.687   |

(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. An engine will enable the A160 to achieve maximum range and endurance while operating on diesel fuel.

- (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 ration of 1.0 hp/lb.

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|        | FY 2003 | FY 2004 | FY 2005 |
|--------|---------|---------|---------|
| Walrus | 0.000   | 0.000   | 10.000  |

(U) This work is a continuation of technologies and concepts previously 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 fly heavier-than-air, unlike earlier generation airships. As a “hybrid aircraft,” it will generate lift through a combination of aerodynamics and gas buoyancy. The program will develop and construct a Walrus Advanced Technology Demonstration (ATD) air vehicle with comparable C-130 airlift capability, and will explore, develop, and demonstrate the system concepts of operation. Scalability of the concept will also be demonstrated. An objective vehicle is envisioned to be capable of lifting over 500 tons across intercontinental distances, being able to transport a Unit of Action (UA) from “Fort-to-Fight” as a complete integrated action-ready package of personnel and equipment. Additionally, Walrus may meet the multi-agency needs of common requirements for extended range airborne patrol, persistence and intra-theater support and re-supply. Two advanced breakthrough technologies that will be investigated in the first phase are: vacuum / air buoyancy compensator tanks, and electrostatic atmospheric ion propulsion. 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 development, design, build and initial flight test of the ATD vehicle.

(U) Program Plans:

- Development of the objective air vehicle design, operational requirements and CONOPs.
- Competitive development of system requirements and preliminary ATD vehicle design based on selected concept options.
- Risk reduction testing in support of ATD and objective air vehicles.
- Complete detailed design ATD air vehicle continuing on to a critical design review.
- Manufacture and fabricate ATD air vehicle.
- Flight test and release to Services for evaluation testing of military utility.

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|                              | FY 2003 | FY 2004 | FY 2005 |
|------------------------------|---------|---------|---------|
| Critical Munition Capability | 0.000   | 2.500   | 3.500   |

(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 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

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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.

(U) Program Plans:

- HyperJam
  - Develop system level requirements.
  - Conduct detailed simulation studies to determine range capability and control requirements.
  - Develop integrated missile concepts with modified Joint Direct Attack Munition (JDAM) for attitude control.
  - Conduct ground experiments to simulate attitude control capability and aerodynamic environment.
  - Conduct flight experiments on F/A-18 to demonstrate integrated system performance.
  
- MAULLM
  - Initiate competitive contracts for system preliminary design.
  - 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).

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

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Modular Blended Wing Body Multi-Role Aircraft (MBWB MRA) | 0.000   | 0.000   | 3.420   |

(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.



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- Demonstrate efficiency and affordability.

|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Advanced Aerospace System Concepts | 1.479   | 2.981   | 1.310   |

(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 new 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.

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

|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Unmanned Combat Air Vehicle (UCAV) |         |         |         |
| PE 0603333F, Air Force             | 17.608  | 0.000   | 0.000   |
| PE 0604731F, Air Force             | 36.756  | 0.000   | 0.000   |
| PE 0207256F, Air Force             | 0.000   | 0.000   | 0.000   |

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|  |         |         |         |
|--|---------|---------|---------|
| Naval Unmanned Combat Air Vehicle (UCAV-N) | FY 2003 | FY 2004 | FY 2005 |
| PE 0603114N                                | 20.280  | 0.000   | 0.000   |
| Joint Unmanned Combat Air System (J-UCAS)  | FY 2003 | FY 2004 | FY 2005 |
| PE 0604731F, Air Force                     | 0.000   | 174.449 | 0.000   |
| PE 0207256F, Air Force                     | 0.000   | 2.305   | 0.000   |
| PE 0603114N, Navy                          | 0.000   | 117.865 | 0.000   |
| PE 0603400D8Z, OSD                         | 0.000   | 0.000   | 284.617 |
| PE 0604400D8Z, OSD                         | 0.000   | 0.000   | 422.873 |
| Unmanned Combat Armed Rotorcraft (UCAR)    | FY 2003 | FY 2004 | FY 2005 |
| PE 0602211, Project 47A, Army              | 10.000  | 0.000   | 0.000   |
| PE 0603003, Project 313, Army              | 0.000   | 14.000  | 20.000  |

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Space Programs and Technology ASP-02  | 111.568 | 201.584 | 249.220  | 233.606 | 261.769 | 296.930               | 327.014 |

(U) **Mission Description:**

(U) A space force structure that is robust against attack represents a stabilizing deterrent against adversary attacks on space assets. In addition to the ability to detect and characterize potential attacks, robustness against attack is provided by proliferation of assets, ready access to space, 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.

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

|   |         |         |         |
|---|---------|---------|---------|
|   | FY 2003 | FY 2004 | FY 2005 |
| Orbital Express Space Operations Architecture | 39.614  | 55.110  | 56.599  |

(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 nanosatellites for inspection to provide data to support

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satellite repair. The Orbital Express advanced technology demonstration will design, develop and test on-orbit a prototype servicing satellite (ASTRO), a surrogate next generation serviceable satellite (NextSat), and the Space Awareness prototype micro-satellite escort, that will provide near-field space situation awareness for U.S. satellites deployed in geo-stationary orbits. The elements of the Orbital Express demonstration 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 Orbital Space Plane and to enable future commercial resupply of the International Space Station. 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.
- Design, fabricate and test on orbit a modular micro-satellite for protection of U.S. geo-stationary satellites.
- 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.

|                              | FY 2003 | FY 2004 | FY 2005 |
|------------------------------|---------|---------|---------|
| Space Surveillance Telescope | 3.966   | 8.921   | 16.673  |

(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.

(U) Program Plans:

- Fabricate and test first curved focal plane tile.
- Fabricate remaining sensor elements.

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- Begin optics fabrication.
- Begin wide-field camera integration.
- Begin telescope integration.
- Complete site selection.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Innovative Space-Based Radar Antenna Technology (ISAT) | 16.699  | 41.208  | 45.000  |

(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 ultra lightweight low-power density RF electronics. An antenna of this size enables a medium Earth orbit (MEO) constellation that provides 24/7 true continuous coverage with as few as eight satellites, as compared to many dozens at low Earth orbit (LEO). In particular, 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 rigidized inflatable structures, and will develop performance predictions on the selected designs as well as lifecycle cost models. These designs will be down selected to carry out a space-based experiment of the critical technologies.

- (U) Program Plans:
- Develop next-generation lightweight electronics, materials and deployment structures.
  - Perform ground-based risk reduction experiments for packaging and deployment mechanisms and materials, including simulation of mechanical and thermal loads.
  - Complete systems designs for space-based experiment; downselect to single design; build, integrate and demonstrate space-based tactical-grade aperture technology.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Microsatellite Tactical Communications Network | 0.000   | 0.000   | 4.900   |

(U) The aim of the Microsatellite Tactical Communications Network (MTCN) effort is the development of advanced, affordable, robust anti-jam satellite communications. This will be accomplished through novel microsatellite spacecraft design, advanced low-weight, highly compactable antennas, and novel cooperative multi-satellite coherent signal combining. Moreover, novel launch vehicle integration and electronic propulsion concepts will be developed that may allow for the deployment of an entire constellation from a single launch.

- (U) Program plans:
- Develop novel MTCN system and spacecraft designs.
  - Develop novel launch dispenser concepts, possibly enabling single launch deployment of the entire constellation.
  - Determine feasibility of novel signal processing concepts to enable robust comms on small platforms.
  - Carry out ground-based proof-of-concept demonstrations.

|           | FY 2003 | FY 2004 | FY 2005 |
|-----------|---------|---------|---------|
| Deep View | 3.976   | 9.520   | 11.000  |

(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 to geo-stationary orbit. The system will be based upon a large aperture imaging radar system redesigned to operate at very high power over very broad bandwidth at W-band. Key technology development will focus on transmitters capable of providing the required power to image at deep-space ranges over full bandwidth and antenna design that maintains necessary form factor over a very large aperture. The capabilities emerging from this program will enable the classification of unknown objects, such as space debris, as well as the monitoring of the health and status of operational satellites.

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- (U) Program Plans:
- Perform transmitter power combiner experiments.
  - Complete transmitter design and radar system design.
  - Begin signal processing software development.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Responsive Access, Small Cargo, Affordable Launch (RASCAL) | 24.374  | 30.302  | 39.750  |

(U) The Responsive Access, Small Cargo, Affordable Launch (RASCAL) program will design and develop a low cost orbital insertion capability for dedicated micro-size satellite payloads. The concept is to develop 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 will be comprised of a reusable airplane-like first stage vehicle called the mass injection pre-compressor cooling (MIPPC) powered vehicle (MPV) and a second and third stage expendable rocket vehicle (ERV). The RASCAL demonstration objectives are to place satellites and commodity payloads, between 50 and 130 kilograms in weight, into low-earth orbit at any time, with launch efficiency of \$20,000 per kilogram or less. While the cost goal is commensurate with current large payload launch systems, the operational system, through production economies of scale, will be more than a factor of three less than current capabilities for the dedicated micro payload size. This capability will 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. This program will utilize reusable aircraft technology for the first stage and will take advantage of low-cost rocket technologies for the expendable upper stages. With recent advances in design tools and simulations, this program will prudently reduce design margins and trade-off system reliability to maximize cost effectiveness. This program will also leverage advancements in autonomous range safety, first-stage guidance; and predictive vehicle health diagnosis, management and reporting to lower the recurring costs of space launch.

- (U) Program Plans:
- Develop Contractor Life Cycle Cost Model (CLCC).
  - Prototype Mass Injection Pre-compressor Cooling (MIPCC) manifold – engine testing.
  - Select preferred system concept(s).
  - Establish Preliminary and Critical Design of full system.
  - Conduct mission cycle testing of the first-stage MPV propulsion in direct connect wind tunnel.



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- Conduct early Risk Reduction testing of subsystems: J-85 and F-100 turbine engine testing with MIPCC for thrust augmentation, aircraft wind tunnel for stability, scaled static fires of hybrid motors, Guidance, Navigation & Control (GN&C) simulation, material coupon testing, and Reaction Control System (RCS) firing.
- Conduct static fire of potential new rocket motor in flight weight configuration.
- Flight test MIPCC equipped aircraft.
- Integrate low cost expendable rocket vehicle and common head steering stage design.
- Develop instrumentation package for maiden payload.
- Conduct two orbital insertion missions for final demonstration.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Tactically Responsive Satellites (TRS) | 2.032   | 5.016   | 3.800   |

(U) The TRS program (formerly titled Low Cost Tactical Imager) 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 to be developed 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.

- (U) Program Plans:
- Develop candidate designs for tactically responsive warfighter payloads.
  - Develop and mature key enabling technologies.
  - Perform ground-based risk reduction experiments including rapid checkout functionality.
  - Design, build and integrate space-based prototype.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Force Application and Launch from CONUS (FALCON) | 7.500   | 17.500  | 25.000  |

(U) The FALCON (formerly HyperSoar) program objectives are to develop and demonstrate technologies that will enable both near-term and far-term capability to execute time-critical, global reach missions. Near-term capability will be accomplished via development of a rocket boosted, expendable munitions delivery system that delivers its payload to the target by executing unpowered glide maneuvers at hypersonic speed. This concept called the Common Aero Vehicle (CAV) would be capable of delivering up to 1,000 pounds of munitions to a target at global distance. A Small Launch Vehicle (SLV) will place CAV at the required altitude and velocity. The FALCON program will develop a low cost, responsive SLV that meets these requirements and demonstrate this capability in a series of flight tests culminating with the launch of a functional CAV. In addition, this SLV will be capable of launching small satellites into sun synchronous orbit. Far-term capability is envisioned to entail a reusable, hypersonic cruise vehicle (HCV) capable of delivering 12,000 pounds of payload to a target 9,000 nautical miles from CONUS in less than two hours. Many of the technologies required by CAV are also applicable to this HCV concept such as high lift-to-drag technologies, high temperature materials, thermal protection systems, and periodic guidance, navigation, and control. Initiated under the Space Vehicle Technologies program, and leveraging technology developed under the Hypersonics Flight (HyFly) program, FALCON will build on these technologies to address the implications of powered hypersonic flight and reusability required to enable this far-term capability. The FALCON program addresses many high priority mission areas and applications such as global presence, space control, and space lift.

(U) Program Plans:

- Complete Common Aero Vehicle (CAV) and Small Launch Vehicle (SLV) system designs.
- Perform periodic trajectory analysis for Hypersonic Cruise Vehicle (HCV).
- Complete HCV system level design.
- Initiate preliminary design of CAV and SLV.
- Perform technology validation for reusable, hypersonic aircraft.
- Conduct critical design review of CAV and SLV, and initiate fabrication.
- Initiate preliminary design of the HCV technology flight demonstration vehicle.
- Conduct CAV flight demonstrations using existing boosters.
- Conduct SLV flight demonstration.

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- Conduct integrated CAV/SLV flight test.
- Conduct critical design review of HCV demonstration system and initiate fabrication.
- Conduct flight-testing of advanced reusable technologies for HCV.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Rapid On-Orbit Anomaly Surveillance and Tracking (ROAST) | 0.000   | 5.000   | 5.000   |

(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, adaptive focal plane array sensors, and efficient space-qualified receivers and processors. The system will feature space-craft technologies, such as structure-integrated propellant tanks and liquid metal reaction wheels, to produce a spacecraft capable of launch from a RASCAL 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 optics fabrication capability.
  - Demonstrate prototype integrated tanks and liquid reaction wheels.
  - Complete telescope design.
  - Complete blue force tracking receiver.
  - Complete focal plane array design lay-out.
  - Complete spacecraft PDR.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| High Frequency Active Auroral Research Project (HAARP) | 11.034  | 16.093  | 15.006  |

(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

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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. Basic and exploratory development research programs are now being conducted routinely with it. 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 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.

(U) An April 2001 Defense Threat Reduction Agency (DTRA) Study indicated that a single low-yield (10-20 kt), high-altitude (125 - 300 km) nuclear detonation (HAND) would enhance the magnetospheric high energy particle density by three orders of magnitude or more, and persist for over a year. This event would disable all low earth orbit (LEO) satellites not specifically hardened to withstand radiation generated by that explosion. The resultant loss of communications, imaging, and weather satellites would have catastrophic global security and economic impacts. Replacing the lost inventory after the fact would cost in the trillions of dollars. The cost of hardening new satellites is also prohibitive. The probability of such an asymmetric threat is not negligible, given the recent nuclear weapon activities in Asia, and the consequences of such a threat are disastrous. HAARP will provide a ground-based testbed for early feasibility examination and tradeoffs of concepts for accelerating the reduction of HAND-enhanced charged particle populations in the radiation belts. Two concepts will be considered: (1) space-based propagation of very low frequency (VLF) electromagnetic waves into the ionosphere in the magnetic field line where the trapped particles are oscillating between magnetic mirror points, causing the particles to be “swept away” ten times faster than the natural decay; and (2) high voltage multi-kilometer Electrodynamic/Static (ED/ES) space tethers to remove highly charged trapped radiation particles as they traverse the magnetic field lines. In both concepts, HAARP would be used to establish the optimum electromagnetic wave/tether parameters for an operational system that could be based on the ground, in space, or both.

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- (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 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Suborbital Space Launch Operations | 2.373   | 1.500   | 0.000   |

(U) The goal of the Suborbital Space Launch 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, fabricate and test a restartable modular propulsion system capable of providing both ascent and descent propulsion.
  - Demonstrate propulsion system operation including restart without maintenance or refueling.
  - Analyze trade space for a technology demonstrator.

|                                | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------|---------|---------|---------|
| Space Assembly and Manufacture | 0.000   | 4.200   | 4.792   |

(U) The goal of the Space Assembly and Manufacture program is to examine and validate technical options for manufacturing 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, nanotube

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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. The program will then culminate in a flight demonstration of a space tug with robotic docking and repositioning in FY 2008. 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.
- Develop imaging, guidance and grapple algorithms and software.
- 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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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |  | R-1 ITEM NOMENCLATURE<br>Advanced Aerospace Systems<br>PE 0603285E, Project ASP-02 |  |

|                         | FY 2003 | FY 2004 | FY 2005 |
|-------------------------|---------|---------|---------|
| Electro-Dynamic Tethers | 0.000   | 0.000   | 2.800   |

(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 provides 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:

- Compete analytical analysis for tether HAND remediation, propulsion and power generation performance expectation.
- Ground test key high-voltage electro-static-like tether components.
- Flight qualify tether space flight experiments payload for placement on a small, high-powered satellite bus.
- Launch and execute tether experiments in LEO: natural-radiation-belt, high-energy electron remediation; orbit-raising and lowering; peak-power production and high-fidelity ground tracking.

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|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Micro Electric Space Propulsion | 0.000   | 0.000   | 3.800   |

(U) The Micro-Electric Space Propulsion program 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.

(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 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 2003 | FY 2004 | FY 2005 |
|--------------------|---------|---------|---------|
| RAD Hard by Design | 0.000   | 7.214   | 10.500  |

(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 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



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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. In FY 2003, this program was funded from PE 0603739E, Project MT-15, Advanced Electronics Technology. The program was moved to Advanced Aerospace Systems because of the applicability of radiation hardened electronics to space applications.

(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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP) | 0.000   | 0.000   | 4.600   |

(U) The Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP) program, expanding on a thrust area initiated under the Space Assembly and Manufacture program (same PE and project), will develop advanced technologies and capabilities required to demonstrate in a Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and the deep space (Super GEO) environment a suite of advanced lightweight microsatellite (spacecraft dry mass on the order of 100 kg) technologies integrated into a high performance microsatellite. The program will integrate a variety of advanced technologies, which have not been previously flight-tested, and may include: lightweight optical space surveillance/situational awareness sensors, lightweight power, chemical and electric propulsion systems, advanced lightweight structures, advanced miniature RF technology including micro crosslink and use of Commercial Off the Shelf (COTS) approaches, active RF sensor technology, COTS processor and software environment, miniature navigation technologies, and autonomous operations. Technologies 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 the possibility of networking microsatellites/modules to create a flexible architecture of assets responsive to multiple missions and threats. If successful, MiDSTEP will demonstrate these technologies in space, and may serve as a testbed for a variety of potential microsatellite applications.

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- (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.

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

|   |                            |                             |                             |
|---|----------------------------|-----------------------------|-----------------------------|
| Orbital Express Space Operations Architecture<br>NASA   | FY 2003<br>9.000           | FY 2004<br>8.000            | FY 2005<br>0.000            |
| High Frequency Active Auroral Research Project (HAARP)<br>PE 0601153N, Navy<br>PE 0602601F, Air Force | FY 2003<br>12.500<br>0.000 | FY 2004<br>15.000<br>10.000 | FY 2005<br>16.000<br>10.000 |
| Force Application and Launch from CONUS<br>PE 0604855, Air Force SPC<br>PE 0604856, Air Force SPC     | FY 2003<br>0.000<br>0.000  | FY 2004<br>24.440<br>12.220 | FY 2005<br>35.362<br>21.610 |

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| COST (In Millions)  | FY 2003 | FY2004  | FY2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost   | 158.847 | 186.748 | 218.151  | 205.378 | 234.063 | 225.293               | 194.381 |
| Electronic Module Technology MT-04  | 21.457  | 17.028  | 17.972   | 18.102  | 19.872  | 20.749                | 20.719  |
| Centers of Excellence MT-07   | 4.756   | 4.000   | 4.000  | 0.000   | 0.000   | 0.000                 | 0.000   |
| Advanced Lithography MT-10  | 33.767  | 33.100  | 24.520   | 0.000   | 0.000   | 0.000                 | 0.000   |
| MEMS and Integrated Micro-systems Technology MT-12  | 27.887  | 26.069  | 45.462   | 48.719  | 52.521  | 33.000                | 3.000   |
| Mixed Technology Integration MT-15  | 70.980  | 106.551 | 126.197  | 138.557 | 161.670 | 171.544               | 170.662 |

**(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 is 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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(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.

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| <b>(U) <u>Program Change Summary:</u> (In Millions)</b> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|---|-----------------------|-----------------------|----------------------|
| Previous President's Budget                             | 158.987               | 174.150               | 172.151              |
| Current President's Budget                              | 158.847               | 186.748               | 218.151              |
| Total Adjustments                                       | -0.140                | 12.598                | 46.000               |
| <br>  |                       |                       |                      |
| Congressional program reductions                        | 0.000                 | -2.002                |                      |
| Congressional increases                                 | 0.000                 | 14.600                |                      |
| Reprogrammings  | 0.300                 | 0.000                 |                      |
| SBIR/STTR transfer                                      | -0.440                | 0.000                 |                      |

**(U) Change Summary Explanation:**

|         |   |
|---------|---|
| FY 2003 | Decrease reflects minor reprogrammings offset by the SBIR transfer.   |
| FY 2004 | Increase reflects congressional adds for advanced lithography programs, crystal materials for electro-optic imaging and communication and 3D imaging, offset by congressional undistributed reductions. |
| FY 2005 | Increase reflects project expansion of MT-12 and MT-15 for Sustainable Micropower Sources, Chip Scale Gas Analyzers and mixed technology programs.  |

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005 | FY 2006  | FY 2007 | FY 2008               | FY 2009 |
| Electronic Module Technology MT-04  | 21.457  | 17.028  | 17.972  | 18.102   | 19.872  | 20.749                | 20.719  |

(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 2003 | FY 2004 | FY 2005 |
| Semiconductor Ultraviolet Optical Sources (SUVOS) | 21.457  | 17.028  | 12.972  |

(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.



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(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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Chemical Engineering in Microsystems (CHEMS) | 0.000   | 0.000   | 5.000   |

(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.

(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 simulant 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.
- 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.

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- 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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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005 | FY 2006  | FY 2007 | FY 2008               | FY 2009 |
| Centers of Excellence MT-07   | 4.756   | 4.000   | 4.000   | 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 factory and initiatives to local area industries to utilize computer-integrated manufacturing technologies and managerial techniques to improve manufacturing productivity and competitiveness. Training includes technologies to significantly reduce unit production and life cycle costs and to improve product quality.

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

|                                 |         |         |         |
|---------------------------------|---------|---------|---------|
|                                 | FY 2003 | FY 2004 | FY 2005 |
| Advanced Flexible Manufacturing | 3.808   | 4.000   | 4.000   |

(U) Program Plan:

- Continue the assessment of the Institute for Advanced Flexible Manufacturing's performance and transition from DoD to state/private support.

|  |         |         |         |
|--|---------|---------|---------|
|  | FY 2003 | FY 2004 | FY 2005 |
| Defense Techlink Rural Technology Transfer Project | 0.948   | 0.000   | 0.000   |

(U) Program Accomplishments:

- Provided 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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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Advanced Lithography MT-10  | 33.767  | 33.100  | 24.520   | 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 2003 | FY 2004 | FY 2005 |
| Advanced Lithography | 23.517  | 23.500  | 24.520  |

(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  $\mu\text{m}$  resolution over field areas in excess of 1000  $\text{mm}^2$ . 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.

- (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 2003 | FY 2004 | FY 2005 |
|---------------------------|---------|---------|---------|
| Laser Plasma X-Ray Source | 2.467   | 3.400   | 0.000   |

- (U) Program Plans:
- Continue development of laser plasma x-ray source technology.

|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Advanced Lithography Demonstration | 3.797   | 3.400   | 0.000   |

- (U) Program Plans:
- Continue development of point source lithography.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Advanced Lithography X-Ray Thin Film Development | 3.986   | 2.800   | 0.000   |

(U) Program Plans:  
 – Continue development of X-Ray mask lithography thin film.

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

- Not Applicable.



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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |         |         |         | R-1 ITEM NOMENCLATURE<br>Advanced Electronics Technology<br>PE 0603739E, Project MT-12 |         |                       |         |
| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005 | FY 2006  | FY 2007 | FY 2008               | FY 2009 |
| MEMS and Integrated Micro-systems Technology<br>MT-12                                       | 27.887  | 26.069  | 45.462  | 48.719   | 52.521  | 33.000                | 3.000   |

(U) **Mission Description:**

(U) The Microelectromechanical Systems (MEMS) program is a broad, cross-disciplinary initiative to develop an enabling technology that merges computation and power generation with sensing and actuation to realize a new technology for both perceiving and controlling weapons systems and battlefield environments. Using fabrication processes and materials similar to those that are used to make microelectronic devices, MEMS 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 2003 | FY 2004 | FY 2005 |
|------------------------|---------|---------|---------|
| Micro Power Generation | 10.824  | 8.101   | 0.000   |

(U) Compact portable power sources capable of generating power in the range of a few hundred milliwatts to one watt are critical to providing power for untethered sensors and other chip-scale microsystems. This program will replace today's technologies relying on primary and rechargeable batteries, which severely limit mission endurance and capabilities, by extending microelectronic machine technology to develop micro-power generators based on mechanical actuation and thermal-electric power generation. Operating with traditional fuels, these micropower generators will be capable of generating sustained power in the desired range for use with remote, field-deployed microsensors and microactuators. The program will also explore innovative micro-scale, integratable power sources to provide high density energy sources.

(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.

|                              | FY 2003 | FY 2004 | FY 2005 |
|------------------------------|---------|---------|---------|
| Bio-Fluidic Chips (BioFlips) | 10.211  | 0.000   | 0.000   |

(U) The Bio-Fluidic Chips program funded the development of totally integrated microfluidic chips to enable ubiquitous yet unobtrusive assessment of the warfighter's body fluids. These microchips integrated detection, diagnostics and treatment in one chip-scale system.

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- (U) Program Accomplishments:
- Demonstrated optimization of sub-systems and components for integration into prototype systems. Sub-systems included: 1) on-chip sample preparation and processing (on-chip flow/concentration regulators, biosignal amplification, on-chip pressure sources, on chip separation/mixing, reagents storage/reconstitution); 2) sample collection (body fluid extractors, concentrators); and 3) antidote synthesis (genetic and antibodies) subsystems.
  - Identified partners in the DoD and other federal agencies for testing prototype systems.
  - Performed preliminary testing of prototype systems for re-evaluation of sub-system functionality.
  - Modified sub-systems based on preliminary testing of prototype systems.
  - Finalized testing of prototype systems to optimize integrated performance.
  - Demonstrated prototype BioFlip systems in DoD laboratories.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Harsh Environment Robust Micromechanical Technology (HERMIT) | 3.910   | 7.100   | 10.190  |

(U) The Harsh Environment Robust Micromechanical Technology (HERMIT) Program aims to demonstrate 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. Although HERMIT realizations of micromechanical RF switches are of particular interest, where sizable power throughputs and impacting operation constitute harsh operational environments, implementations for 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.

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- (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.
  - 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 2003 | FY 2004 | FY 2005 |
|--------------------------|---------|---------|---------|
| Chip-Scale Gas Analyzers | 0.000   | 5.000   | 10.000  |

(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.

- (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.

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- 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).
- Implement fully functional, MEMS-enabled gas separation analyzers with power consumptions small enough for autonomous, remote operation and with control electronics integrated directly.

|               | FY 2003 | FY 2004 | FY 2005 |
|---------------|---------|---------|---------|
| MEMS Exchange | 0.000   | 3.868   | 6.344   |

(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.

(U) Program Plans:

- Demonstrate online software capable of error checking and optimizing process flows 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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Micromechanical Computation and Data Storage | 0.000   | 2.000   | 5.700   |

(U) The Micromechanical Computation and Data Storage Program aims to harness the low loss and low thermodynamic noise floor inherent in mechanical structures to (1) attain computational and signal processing circuits with unprecedented robustness and record low power consumption; and (2) to realize archival data storage devices with better than 1000Gb/in<sup>2</sup> densities. The key to attaining such performance is the recognition that mechanical structures are circuit elements in their own right, each with the capability to filter signals via their resonance properties, switch signals via mechanical actuation, and distort/shape/amplify signals via their nonlinearities, all at bandwidths rivaling those of transistors when implemented on the nano-mechanical scale. When connected into larger circuit networks, such mechanical elements can then be structured to perform increasingly complex functions, including filtering, mixing, amplification, and A/D or D/A conversion, all with dynamic ranges and power usages potentially better than exhibited by transistor-based counterparts. For data storage, the key approach in this program that allows it to break the 100Gb/in<sup>2</sup> thermodynamic barrier presently constraining conventional magnetic storage approaches is the use of MEMS technology to store, access, and erase data as tiny pits, phase changes, or even molecular changes (e.g., in a DNA chain). One possible rendition might use a MEMS based probe to manipulate the bits. A successful program in micromechanical computation and data storage would not only make single-chip (electrical or mechanical) computers possible, but would also enable circuits that can be powered by means other than electrical energy (e.g. direct chemical energy is possible), and that are practically immune to Electro-Magnetic Interface (EMI) and robust against radiation.

(U) Program Plans:

- Demonstrate mechanical circuit elements capable of manipulating a set of signal types (e.g., mechanical, electrical, acoustic) in various domains (e.g., frequency, time).
- Establish the feasibility of writing, reading, and erasing data using alternative storage mechanisms with higher thermodynamic density limits (> 1000Gb/in<sup>2</sup>); (e.g., structural change-based (pits), phase change-based, DNA-chain-change based).
- Demonstrate methods for improving the data rate of data storage devices based upon the above techniques (e.g., by using MEMS-enabled massively parallel construction) while maintaining high read/write reliability.
- Design and demonstrate mechanical circuit networks capable of performing needed computational or signal processing functions (e.g., addition, multiplication, mixing, amplification, A/D conversion) with extremely low power consumption, and with immunity to EMI or radiation interference.

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|                                   | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Low Power Micro Cryogenic Coolers | 0.000   | 0.000   | 5.228   |

(U) The Low Power Micro Cryogenic Cooler program will attain superior performance in micro-scale devices (e.g. Low Noise Amplifier (LNA's) IR detectors, RF front-ends, superconducting circuits) by cooling selected portions to cryogenic temperatures. The key approach in this program that should allow orders of magnitude power savings, is to selectively cool only the needed volume/device via MEMS-enabled isolation technologies. Such an approach will benefit a large number of applications where performance is determined predominately by only a few devices in a system, e.g., communications where the front-end filter and LNA often set the noise figure; and sensors, where the transducer and input transistor in the sense amplifier often set the resolution. MEMS technology will also be instrumental for achieving micro-scale mechanical pumps, valves, heat exchangers, and compressors, all needed to realize a complete cryogenic refrigeration system on a chip.

(U) Program Plans:

- Obtain high thermal isolation using MEMS technology, despite high surface-to-volume ratios of micro-scale elements.
- Demonstrate micro-scale compressors with sufficient efficiency for low power operation.
- Demonstrate heat exchangers, Joule-Thompson plugs, valves, pumps, all needed for cryo-cooler implementation.
- Integrate micro cooler components together with sufficiently isolated devices to-be-cooled to yield a single chip system.

|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Sustainable Micro-Power Sources | 0.000   | 0.000   | 8.000   |

(U) The Sustainable Micro Power Sources program will harness ultra-high density nuclear fuels, or readily available bio-fuels (e.g., carbohydrates: glucose, sucrose, perhaps obtained directly from a soldier's MRE, or from tree sap), to attain long-lived, on-demand power sources for soldier electronics and for distributed autonomous sensors. In the nuclear area, two approaches are of primary interest: (1) accelerator-activated alpha-emitting radioisotopes with plasma-based charge collectors; and (2) beta-emitting charge-collecting mechanical devices that reciprocate with charge build-up. On the bio-side, fuel cells using enzymatic or microbial catalysts to break down carbohydrate fuels into hydrogen ions and electrons to be used to power a circuit load are of high interest. Extensions of this concept to allow photosynthesis of glucose fuels are also of



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interest, as they could make possible ultra-long term power sources. In making available either long-lived nuclear sources, or MRE- or plant-fueled bio-fuel cells, the success of a Sustainable Micro Power Sources program should make available “electricity- on-demand” for various soldier electronics and for long-term autonomous sensors (e.g., cognitive arthropods).

(U) Program Plans:

- Establish the feasibility of techniques 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.
- Demonstrate efficient nuclear-to-electrical or mechanical energy conversion using MEMS-based mechanisms that minimize the loss of energy carriers.
- Demonstrate micro bio-fuel processors capable of removing unwanted species in fuel mixtures generated from available food.
- Demonstrate fuel flexible bio fuel cells, some of which may employ photosynthesis for sustainable power output lifetimes.

|                                | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------|---------|---------|---------|
| MEMS Micro-Actuator Technology | 1.423   | 0.000   | 0.000   |

(U) Program Accomplishments:

- Initiated novel design concepts of MEMS Micro-Actuators.

|                                      | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| MEMS Deep Silicon Etching Technology | 1.519   | 0.000   | 0.000   |

(U) Program Accomplishments:

- Continued MEMS Deep Etching program in conjunction with Army Research Laboratory.

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

- Not Applicable.

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Mixed Technology Integration MT-15  | 70.980  | 106.551 | 126.197  | 138.557 | 161.670 | 171.544               | 170.662 |

(U) **Mission Description:**

(U) The goal of the Mixed-Technology Integration project is to leverage advanced microelectronics manufacturing infrastructure and DARPA component technologies developed in other projects to produce mixed-technology microsystems that will revolutionize the way individuals see, hear, taste, smell, touch and control their environment at a distance. 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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| RF Lightwave Integrated Circuits (RFLICS) | 8.478   | 4.769   | 0.000   |

(U) The Radio Frequency (RF) Lightwave Integrated Circuits (RFLICS) program is demonstrating enhanced performance capabilities of RF systems enabled by integration of lightwave and RF technologies to route, control, and process analog RF signals in the 0.5 – 50 Ghz range.

(U) **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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Nano Mechanical Array Signal Processor (NMAASP) | 18.106  | 16.014  | 2.000   |

(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.

(U) **Program Plans:**

- Demonstrate fabrication techniques to control surface morphology, geometry, and material properties at the sub-micron scale.

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- 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 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Digital Control of Analog Circuits RF Front Ends | 12.987  | 16.732  | 13.102  |

(U) Digital Control of Analog Circuits will demonstrate analog/RF electronic components with the ability to self-assess and adapt in real time (sub microseconds), by self-tuning its impedance-matched networks, extending the operational performance of analog components to the intrinsic semiconductor device limits. This technology will result in a new generation of analog, microwave and millimeter wave components with >150X improvements in power-bandwidth, linearity-efficiency products.

(U) 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.
- Demonstrate MEMs tunable device optimization (<1 microsecond, 10:1 tuning ratio).
- Fabricate tunable MEMs control Integrated Circuits (ICS).
- Fabricate self-assessment control Integrated Circuits (ICS).
- Demonstrate device and algorithm concepts for intelligent self-assessment of analog functions.
- Demonstrate device concepts for  $10^5$  microsecond actuation time of impedance matched networks.
- Complete design concept for adaptable RF components.
- Demonstrate concept of digital assessment of analog device.

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- Demonstrate reconfigurable network concept for 10<sup>5</sup> microsecond actuation time of impedance matched networks.
- Validate concept of adaptable RF components by demonstrate digital control of analog circuits.
- Identify component requirements.
- Initiate Phase III – component demonstration.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Chip Scale Wavelength Division Multiplexing (WDM) | 16.935  | 18.763  | 15.500  |

(U) The goal of the Chip Scale Wavelength Division Multiplexing (WDM) program is to develop new materials, components and sub-systems for use in wavelength division multiplexing based optical communications, delivering high capacity, mission adaptable networks for use in data intensive military weapons systems.

(U) 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.
- Determine fiberoptic 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.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Optical Code Division Multiple Access (CDMA) | 0.000   | 7.306   | 6.767   |

(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.

- (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.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Optical Phased Array of Phased Arrays (PAPA) | 0.000   | 0.000   | 4.000   |

(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.



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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Data in Optical Domain Network (DoD-Network) | 0.000   | 10.235  | 10.600  |

(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.

- (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 picoseconds optical time delay.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Large Area Distributed Microelectronics | 0.000   | 5.500   | 7.400   |

(U) This 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, multilayer routing and 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 order of magnitude improvements in performance and/or cost. Examples of applications include: control surfaces for an autonomous precision guided parafoil and controlled air boundary layers for reduction in drag for underwater vehicles; beam steered acoustic arrays with large apertures to achieve order of magnitude improvements in angle of coverage and signal to noise ratios; early warning threat detection and localization using a large area inflatable structure with woven antennas and electronics for high bandwidth communications; and aircraft or UAV wing skins for chem/bio monitoring.

(U) Program Plans:

- Develop enhanced transistors compatible with low cost, large area fabrication.
- Develop methods to print active circuits on large area and flexible circuits.
- Develop techniques to wirelessly communicate between circuit blocks over a distributed electronics surface.
- Develop novel circuit/microarchitectures to enhance system performance for demanding electronic applications.
- Demonstrate examples of large area and/or flexible substrate distributed electronics to address difficult problems in sensor networks, physical security systems, or radar beam forming/steering.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Microantenna Array Technology & Applications (MIATA) | 0.000   | 8.000   | 9.000   |

(U) This program was formerly named Submillimeter Wave Imaging Technology. The goal of this program is to develop arrays of low-cost microantennas that can simultaneously sense both Millimeter Wave (MMW) and IR scenes along with compact MMW designator sources for

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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.

(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 a 8x8 array.
- Achieve 95 GHZ: NETD  $\leq$  2 K in a 8x8 array.
- Achieve 8-12 um: NETD  $\leq$  0.02 K in a 64x64 array.

|                               | FY 2003 | FY 2004 | FY 2005 |
|-------------------------------|---------|---------|---------|
| Ultra Wide Band Array Antenna | 0.000   | 6.232   | 5.260   |

(U) The Ultra Wide Band Array Antenna effort will develop array antenna and beamforming technology to support steering from ten to one hundred independent beams with instantaneous bandwidths in excess of 100:1 from an array antenna. Frequency ranges of interest are: 20 MHz to 3 GHz, 100 MHz to 20 GHz and 500 MHz to 50 GHz.

(U) Program Plans:

- Initiate component design and simulation - radiating element, low noise amplifier, 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 for 10 elements.
- Complete prototype integration and test - prove multi-octave, multi-beam performance.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Flexible Nanocomposite Organic Photovoltaic Cells | 0.000   | 8.000   | 10.000  |

(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.

- (U) Program Plans:
- Deliver 2 cm<sup>2</sup> PV cell with increased efficiency from < 3% to 20% .
  - Use plastic or fabric substrates in transparent electrode and heterojunction stability.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Laser-Photoacoustic Spectroscopy (L-PAS) | 0.000   | 0.000   | 7.068   |

(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.

- (U) Program Plans:
- Demonstrate working prototypes that have a sensitivity to <1ppb at a false alarm rate of better than 10<sup>-6</sup>.
  - 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.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Broadband Covert Optical Device Technology | 0.000   | 0.000   | 5.000   |

(U) This program will develop broadband laser sources and detector arrays in which each pixel is a high speed spectrometer. The laser sources will be diffraction limited output devices with linewidths greater than 50% of the central frequency (“octave lasers”). These sources will have outputs that span across the entire visible region, or across the entire Near Infrared Radiation/Short Wave Infrared (NIR/SWIR) band, and will be continuous wave devices. The receivers will be large area focal plane arrays in which each pixel is a high speed spectrometer, capable of nanosecond temporal resolution and simultaneous acquisition in ten to twenty distinct spectral bands across the spectral region of interest.

(U) Program Plans:

- Develop very broadband diffraction limited Continuous Wave (CW) optical sources.
- Develop matching detector focal plane arrays for multispectral imaging, in which each pixel is a multiband high bandwidth (speed) spectrometer with simultaneous detection in each band.
- Demonstrate optical coding/decoding by imprinting and interpreting high-speed pseudo-random noise (e.g.) signals on the ultra broadband carrier, for secure communications, designation, optical augmentation, and remote sensing.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Hierarchical CAD Tools for Noise Tolerant Mixed Signal Electronic Circuits | 0.000   | 0.000   | 5.000   |

(U) The program will develop hierarchical Computer Aided Design (CAD) tools to significantly improve the ability to design mixed signal circuits that are exposed to noise in harsh environments, e.g., complex electromagnetic environments with radiation effects due to incidence of high energy particles. Specifically, the program will develop and demonstrate a new generation of CAD tools and libraries with physics-based models of single event effects, total ionizing dose and prompt dose. The integrated CAD capability will incorporate (1) a novel “flow up” paradigm, where parameters, such as current leakage, doping profiles, charge trapping, fluence, linear energy transfer (LET), carrier transport, etc., will flow up from device and compact models into a behavioral circuit simulator and synthesis backbone and (2) synthesis tools to perform system wide radiation and electromagnetic interference trade-off analysis and optimization.

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- (U) Program Plans:
- Develop fast parasitic extraction of SEE (Single Event Effects), TID (Total Ionizing Dose) and prompt dose effects and demonstrate parasitic aware routing, placement and layout tools.
  - Demonstrate feasibility of using models to migrate designs between different technologies/processes quickly and efficiently.
  - Develop models to demonstrate the automated synthesis, verification and optimization of noise-tolerant circuit architectures.
  - Demonstrate the ability to predict optimal tradeoffs (between performance and radiation variables), achievable over the span of radiation aware design space.
  - Implement model libraries for components and sub-blocks/circuits based on coupled electrical/radiation performance characteristics.
  - Develop a plan to interface the models and libraries with either new or existing design environments (i.e., design flows) for electronic circuits.
  - Conduct performance verification and validation studies (on a military relevant mixed signal circuit) to demonstrate the capabilities of the design tools.

|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Ideal Radio Frequency (RF) Link | 0.000   | 0.000   | 5.000   |

(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 techniques 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.

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- Establish program metrics for optimum RF link demonstration.
- Initiate component development and heterogeneous integration demonstrations.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Silicon RFICs with MEMS For Fully Programmable RF/mmwave Electronics | 0.000   | 0.000   | 5.000   |

(U) This program will provide new systems capabilities for integrated RF microsystems by developing material and device processing technologies for integrating microelectromechanical RF structures (MEMS) with integrated RF/microwave/millimeterwave (MMWAVE) electronics to form reconfigurable, multi-functional active RF surfaces. The integration of massive numbers of miniaturized MEMS structures with advanced control and RF processing will enable fully programmable metallic and active RF processing surfaces which will be capable of rapid reconfiguration under electronic control to adapt their resonant and out-of-band characteristics, creating new classes of components that can rapidly and efficiently span electromagnetic bands with high signal-to-noise ratio and minimal losses. These highly integrated active RF elements will consist of efficient, low loss, low power, agile transceivers with high speed digital RF memories, precision analog/mixed signal circuits, and MEMS sensors and structures for actively reconfiguring the resonant structures and devices.

(U) Program Plans:

- Develop and demonstrate fabrication technologies for critical high performance electronics and micromachined components with very high quality factors and high performance radio-frequency characteristics compatible with integration into active radio frequency surfaces.
- Develop and demonstrate chip and device-scale electromagnetic isolation approaches.
- Complete development of scaled fabrication process for reducing power and insertion loss of integrated radio-frequency components.
- Complete measurements of radio-frequency parameters of integrated radio-frequency components and perform de-embedding analysis.
- Demonstrate integration technologies that result in the ability to combine high speed analog/mixed signal electronics with digital control devices and with micromachined devices to form active surfaces for agile radio-frequency microsystems.
- Develop control algorithms for controlling the active electronics and micromachined components across wide dynamic range and bandwidth for active radio-frequency surface applications.
- Complete far-field and power measurements of fully programmable radio-frequency active surface microsystem.

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|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Liquid Electronics Power Source | 0.000   | 0.000   | 5.000   |

(U) The Liquid Electronics Power Source program will develop a technology base for the development of modules and systems capable of efficiently converting radiation energy into electrical power in the hundreds of KW to MW range. By coupling experience in the chemistry, physics, materials and engineering communities, it is envisioned that a new class of electronics materials based on liquid semiconductors can be developed and engineered into unique structures, devices and modules to allow for efficient, direct conversion of radiation energy with relatively high specific power. Technologies will be developed in this program to overcome specific hurdles of converting radiation energy directly into electricity. Included in the technology development will be alphavoltaics, betravoltaics, direct fission conversion, thermoelectric, thermionics and themophotovoltaics.

(U) Program Plans:

- Control radiation and electron transport in novel chemical systems and engineered structures.
- Synthesize new compositions of matter leading to enhanced materials properties.
- Model cooperative or parasitic effects associated with scaling.
- Transfer radiation particles from sources to converters.
- Develop novel hybrid approaches to couple various conversion technologies.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Intelligent Mixed-Signal Microsystems Technology (IMMST) | 0.000   | 0.000   | 5.000   |

(U) The overall goal of the IMMST program is to significantly advance analog/digital (A/D) conversion technology for insertion into a wide variety of military platforms. A specific goal is a one hundred fold improvement in the data conversion metric (bandwidth X resolution/power). A promising approach is to develop and implement new high performance architectures that overcome the limitations of current mixed signal circuits by harnessing analog pre-processing functions with the enormous calculational power of the most aggressive digital CMOS technology. This



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program will seek new, innovative approaches to analog/digital (A/D) architectures for refinement and incorporation into Defense sensor systems. The resulting technology will impact many Defense communications, radar, and Signal Intelligent (SIGINT) systems.

- (U) Program Plans:
- Identify application for adaptable A/D, components requirements, and technical challenges.
  - Identify concepts for adaptable A/D functions.
  - Demonstrate algorithms and circuits for architecture optimizers.
  - Complete design concepts for adaptable A/D converter architectures.
  - Demonstrate adaptability concepts in mixed signal circuits.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Novel Crystal Components for Imaging and Communications | 1.614   | 2.125   | 0.000   |

(U) The goal of this program was to develop novel imaging technologies utilizing infrared (IR) and crystal growth approaches.

- (U) Program Plans:
- Continue the development of novel crystal components.

|                                  | FY 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Steered Agile Laser Beams (STAB) | 12.860  | 0.000   | 0.000   |

(U) The Steered Agile Laser Beams (STAB) program developed small, lightweight laser beam scanning technologies for the replacement of large, heavy gimbaled mirror systems. New solid state/micro-component technologies such as optical MEMs, patterned liquid crystals and diffractive micro-optics was used to build small, ultra-light, rapidly steered laser beam sub-systems.

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- (U) Program Accomplishments:
- Analyzed system concepts that were used to develop design goals for assembled components.
  - Fabricated individual laser beam steering components (lasers, diffractive optics, MEMS sub-assemblies, detectors, filters and integrated circuits).
  - Resolved component interface issues in preparation for breadboard development.
  - Evaluated competing laser beam steering component technologies and down-selected to the most promising approaches.
  - Completed prototype design studies.
  - Assembled and tested components suitable for use in prototype demonstration and evaluation.
  - Assessed performance characteristics of the prototypes and made recommendations for future development.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Electronic & Photonic Integrated Circuits on Silicon (EPIC) | 0.000   | 0.000   | 5.500   |

(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 it 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.

- (U) Program Plans:
- Demonstrate low-loss waveguides connecting optical gates and increased dynamic range for the logic gates.
  - Demonstrate integrated processing functions such as adders and shift registers, requiring integration of 3-10 logic gates.

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|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| 3-D Imaging Technology Development | 0.000   | 2.125   | 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.

|                    | FY 2003 | FY 2004 | FY 2005 |
|--------------------|---------|---------|---------|
| Mil-Tech Extension | 0.000   | 0.750   | 0.000   |

(U) This effort aims to develop new technologies in military-industrial infrastructure.

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

- Not Applicable.

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| <b>COST (In Millions)</b>  | <b>FY 2003</b> | <b>FY2004</b> | <b>FY2005</b>   | <b>FY 2006</b> | <b>FY 2007</b> | <b>FY 2008</b>               | <b>FY 2009</b> |
| Total Program Element (PE) Cost  | 115.654        | 193.562       | 225.784   | 222.153        | 245.421        | 257.002                      | 279.250        |
| Command & Control Information Systems CCC-01   | 25.661         | 44.408        | 56.629  | 56.148         | 65.388         | 82.354                       | 98.960         |
| Information Integration Systems CCC-02   | 69.165         | 101.399       | 103.146   | 110.230        | 121.406        | 116.078                      | 121.777        |
| Asymmetric Systems CCC-03  | 20.828         | 0.000         | 0.000   | 0.000          | 0.000          | 0.000                        | 0.000          |
| Classified CCC-CLS   | 0.000          | 47.755        | 66.009  | 55.775         | 58.627         | 58.570                       | 58.513         |

**(U) Mission Description:**

(U) This program element is budgeted in the Advanced Technology Development Budget Activity because its purpose is to demonstrate and evaluate advanced information systems research and development concepts.

(U) The goals of the Command and Control Information Systems project are to develop and test innovative, secure architectures and tools to enhance information processing, dissemination and presentation capabilities for the commander. This will give the commander insight into the disposition of enemy and friendly forces, a joint situational awareness picture that will improve planning, decision-making and execution support capability and provide secure multimedia information interfaces and assured software to “on the move” users. Integration of collection management, planning and battlefield awareness programs is an essential element for achieving battlefield dominance through assured information systems.

(U) The goals of the Information Integration Systems project are to take diverse data inputs from a variety of sources, efficiently disseminate the information, and perform distributed and dynamic all-source correlation and fusion to produce an integrated, geo-spatially referenced, battlefield database and knowledge-base. The principal element of this project is assured communications using standard and non-traditional means.

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| <b>(U) Program Change Summary:</b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|---|-----------------------|-----------------------|----------------------|
| Previous President's Budget                             | 117.164               | 242.738               | 279.855              |
| Current President's Budget                              | 115.654               | 193.562               | 225.784              |
| Total Adjustments                                       | -1.510                | -49.176               | -54.071              |
| <br>  |                       |                       |                      |
| Congressional program reductions                        | 0.000                 | -51.176               |                      |
| Congressional increases                                 | 0.000                 | 2.000                 |                      |
| Reprogrammings  | -1.510                | 0.000                 |                      |
| SBIR/STTR transfer                                      | 0.000                 | 0.000                 |                      |

**(U) Change Summary Explanation:**

|         |   |
|---------|---|
| FY 2003 | Decrease reflects minor reprogramming.  |
| FY 2004 | Decrease results from congressional termination of the Asymmetric Systems Project (CCC-03), reductions to the Collaborative Operational Planning Environment and Adaptive Waveforms programs and undistributed reductions, offset by an add for secure digital coherent optical communications. |
| FY 2005 | Decrease reflects the elimination of Project CCC-03 and rephasing of the THOR program.  |

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| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |                |                | <b>R-1 ITEM NOMENCLATURE</b><br>Command, Control and Communications Systems<br>PE 0603760E, Project CCC-01 |                |                |                              |                |
| <b>COST (In Millions)</b>  | <b>FY 2003</b> | <b>FY 2004</b> | <b>FY 20054</b>  | <b>FY 2006</b> | <b>FY 2007</b> | <b>FY 2008</b>               | <b>FY 2009</b> |
| Command & Control Information Systems CCC-01   | 25.661         | 44.408         | 56.629   | 56.148         | 65.388         | 82.354                       | 98.960         |

**(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 nor 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. They 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. They provide secure multimedia information interfaces and assured software 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. It is essential that DoD systems deliver and protect information and assure the availability of associated services – particularly in a stressed environment. Included in this project are Organically Assured and Survivable Information Systems (OASIS), Active Templates (AcT), Joint Air/Ground Operations: Unified Adaptive Replanning (JAGUAR), Advanced Ground Tactical Battle Manager, Effects Based Network Targeting, Predictive Battlespace Awareness, Banshee, Comprehensive Force Protection, Urban Commander, and Command and Control for CollaboRobotic Systems (C<sup>3</sup>RS).

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

|       | FY 2003 | FY 2004 | FY 2005 |
|-------|---------|---------|---------|
| OASIS | 17.493  | 9.227   | 0.000   |

(U) The Organically Assured and Survivable Information Systems (OASIS) program develops defenses against sophisticated future cyber attacks. The program supports sustained operation of mission-critical functions in the face of cyber attacks against DoD information systems. The goal is to develop and demonstrate organically survivable systems. OASIS delivers technologies that counter successful intrusions by means of tolerance and self-healing properties.

(U) The OASIS Demonstration/Validation program deals with the systems aspect of the intrusion problem. It integrates prevention, detection, response and tolerance technologies into a military system to significantly improve the survivability of the system in the face of a large-scale cyber attack.

**(U) Program Plans:**

- OASIS.
  - Demonstrate an experimental intrusion-tolerant database from commercial off-the-shelf components.
  - Prototype and evaluate a framework for tolerating intrusions in large-scale, heterogeneous, networked computing enterprises.
  - Build a distributed architecture for deploying intrusion tolerance mechanisms featuring explicitly stated but flexible tolerance policy.
  - Develop an integrity and availability framework that combines passive intrusion tolerance and active intrusion recovery mechanisms.
  
- OASIS Demonstration/Validation.
  - Integrate OASIS, other DARPA and commercial technologies to develop and demonstrate a survivable variant of the Joint Battlespace Infosphere (JBI).

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- Demonstrate effectiveness of survivable architectures in the face of a determined cyber attack on critical military information system. The measure of success: continuation of critical functionality through a sustained cyber attack.
- Validate survivability claims of technologies using recognized methodologies on operational systems.
- Create novel approaches to composing assurance cases for large-scale systems.

|                        | FY 2003 | FY 2004 | FY 2005 |
|------------------------|---------|---------|---------|
| Active Templates (AcT) | 3.836   | 2.968   | 0.000   |

(U) The Active Templates (AcT) program is producing robust, lightweight software technologies to improve Special Operations Forces mission planning and execution. Active Templates are distributed applications whose variables are linked to live data feeds and external problem-solving algorithms. AcT helps 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 are designed to be easily tailored, networked, noise-tolerant, user-supported, scalable, and widely adopted. AcT enables special operations planners to create plans six times faster, improve plan quality by considering up to eight times more options, reduce staff-hours required to track and coordinate missions by 60 percent, and enhance 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:
- Develop a data representation and template library for critical planning parameters for template adaptation and merging.
  - Demonstrate advanced tools for extending term-ontology to avoid duplication and conflicting semantics.
  - Develop a planning and execution shell including tools for template development such as selecting and tailoring dependencies and problem solving algorithms.
  - Incorporate advanced problem solvers like generative planning, temporal/uncertain reasoning, and triggering for complex events.



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- Demonstrate temporal, spatial, and forms-based mission planning and execution control tools.
- Measure their effectiveness in special operations exercises.
- Transition to U.S. Special Operations Command (SOCOM) and to all theater special operations commands.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Joint Air/Ground Operations: Unified, Adaptive Replanning (JAGUAR) | 0.710   | 8.298   | 11.929  |

(U) The Joint Air/Ground Operations: Unified, Adaptive Replanning (JAGUAR) (formerly Advanced Sensor/Strike Battle Manager) program improves air operations staff conduct of complex campaigns that employ new air platforms featuring precision sensors, precision weapons and communications relays. JAGUAR technology makes use of a) targeting information, both for sensor targets and for strikes, expressed both as point targets and area targets (search, combat air patrol); b) rules of engagement and procedural constraints such as airspace restrictions; and c) availability of platforms, weapons, sensors and communications equipment. From this information JAGUAR produces ingress routes, flight schedules and patrol zones, while assuring airspace and electronic deconfliction. It allows pilots and commanders either to choose conventional tactics or to invent unconventional operations. In the latter case, the system captures the innovation and makes it available for future mission plans. JAGUAR monitors actual plan execution against expected results and alerts commanders to significant differences. It captures statistical descriptions of insignificant differences to help assess the robustness of future plans.

(U) Program Plans:

- Equip a training facility with software tools and human observers to capture plans as they are 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 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Advanced Ground Tactical Battle Manager | 2.841   | 6.000   | 9.000   |

(U) The Advanced Ground Tactical Battle Manager program develops 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. It elicits skeletal courses of action through a graphical interface with unit commanders and extends those plans by applying templates for tactical operations. Adversarial reasoning techniques are used to identify vulnerabilities in the extended plan. Finally, it proposes workarounds or embellishments to reduce those vulnerabilities. A variant of the program would issue plans to subordinate unit commanders and human controllers, and possibly also push necessary elements of the plan to automated platforms or automated battle managers.

- (U) Program Plans:
- Develop an exercise environment with the Marine Corps Warfighting Lab.
  - Define interfaces to existing Marine command and control systems.
  - Develop prototype tools to augment capability.
  - Conduct experiments to ascertain values of tools.

|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Effects Based Network Targeting | 0.781   | 0.000   | 0.000   |

(U) The Effects Based Network Targeting program developed technology to identify, find vulnerabilities in, target and anticipate workarounds in enemy networks. These techniques use all-source information to continuously update models of adversary networks. Program technology applies to any kind of network. Examples include air defense, military C2, telecommunications, transportation (land, rail, air, and water) and energy (fuel, coal, and electric power). This program has moved to PE 0603766E, Project NET-01.

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- (U) Program Accomplishments:
- Identified real-world examples of complex network effects, in conjunction with existing target analysis organizations.
  - Determined the network models required to analyze those effects and the sources of information available to update them.

|                                  | FY 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Predictive Battlespace Awareness | 0.000   | 5.000   | 7.000   |

(U) The Predictive Battlespace Awareness program will develop technology to predict the range of an opponent's future actions. It will enable commanders to preposition sensors, weapons and information to counter the opponent's actions. The program develops model- and knowledge-based techniques to predict areas of operation and operational and tactical objectives. It supports the modeling of large-scale courses of action. Program techniques permit on-the-fly tailoring of models and contextual knowledge and leverage knowledge of sensor effectiveness, mobility factors and tactical templates and target characteristics. It is developing techniques for variable-fidelity prediction, such as the ability to predict 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 effective use of sensors and other resources in proactive modes. The program empowers commanders to avoid canned responses. It supports rapid incorporation of insights about new enemy strategies, capabilities, and tactics from peacetime to heat of battle. The program significantly enhances 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 realistic 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., for 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.

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|                                | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------|---------|---------|---------|
| Comprehensive Force Protection | 0.000   | 3.500   | 7.000   |

(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. It includes wide-area sensors and platforms to maintain continuous surveillance of the camp area. The sensors detect potential intruders and weapon launches. It also includes a suite of airborne sensor platforms that can be tasked rapidly to investigate potential threats or to 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 to authorize precision weapons to engage them. 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.
- Emplace 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 a variety of 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.
- Iterate and demonstrate the final system in continuous operation at a CONUS base.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Urban Commander (formerly Collaborative Operational Planning Environment) | 0.000   | 9.415   | 17.200  |

(U) The Urban Commander program develops automated tools to help ground commanders construct detailed, realistic operational plans, particularly in nontraditional and urban environments. Partial plans are represented in hierarchical task networks and visualized through synchronization matrices, icon overlays, or tactical sketch animations. Commanders and staff modify, refine, and extend a plan through voice, sketching and semi-structured input. The system links plan fragments constructed at different sites, transfers information among related parts of the plan 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 dismounts equipped with advanced heads-up displays and helmet-worn sensors. Finally, the system continuously assesses progress against the plan and alerts users to significant deviations.

- The Urban Commander effort develops planning and control tools tailored to dismounted operations in complex urban environments. Urban warfare combines limited sightlines and mobility with ever-insufficient knowledge of the disposition of enemy combatants, civilians, and the structures they occupy. Urban Commander forms a command and control substrate that enables ground forces, including vehicles and dismounts, to rapidly coordinate actions as the situation and commanders' knowledge of the situation, change. Elements of the Urban Commander program include 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 a situation and make plans to deal with it; and 4) analysis tools, to suggest locations and types of potential threats.
- The Multispectral Adaptive Networked Tactical Imaging System (MANTIS) effort develops, integrates and demonstrates a soldier-worn visualization system. The system consists of five elements: 1) a head-mounted multi-spectral sensor suite with a high resolution visor display; 2) an inertial navigation system; 3) a global positioning system (GPS); 4) a soldier-worn processor; 5) a high bandwidth transceiver; and 6) a power supply. It provides the warfighter with digitally fused, multi-spectral video imagery in real time from the helmet-mounted sensors. The system fuses imagery in the Visible/Near Infrared (VNIR, .4-9 microns), the Short Wave Infrared (SWIR, 1-2 microns) and the Long Wave Infrared (LWIR, 8-12 microns) frequency bands. It displays the fused imagery on the helmet-mounted visor. The warfighter sees where the enemy cannot. MANTIS gives warfighters the advantage in operations at night and in smoke and

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fog. The soldier-worn, high-speed processor adaptively generates an optimized image under variable battlefield conditions. This process takes advantage of the unique signatures in each of the spectral regions. The system also allows the soldier to record the sensor video, and then play it back after taking cover. The record and playback feature includes electronic zoom, scroll, pan and panoramic image stitching. This furnishes a larger field of view to enhance context. The MANTIS INS and GPS devices provide precise soldier location and pose estimation, on which the digital display overlays battlefield information. In this way MANTIS furnishes the warfighter with augmented reality and increased situational awareness. The warfighter can share his position and images with others in real time by means of a high-bandwidth transceiver. The transceiver also allows the soldier to receive images and information from remote sensors. The coupling of the imaging system with the INS/GPS gives the soldier a “point-click-kill” capability for targeting smart weapons fired from elsewhere.

(U) Program Plans:

- Urban Commander.
  - Identify a set of urban combat scenarios ranging from peacekeeping to aggressive assault.
  - Document sets of mission tasks out of 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 a variety of scenarios and force structures.
  - Develop tools to visualize, edit, modify and assemble new plans from mixed-mode human interaction at one location.
  - Develop mechanisms to define and enforce policies limiting the aspects of a plan deemed relevant to each location.
  - Construct protocols to propagate changes made at one location to other 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 suggestion of useful corrections.
  - Conduct a series of laboratory evaluations with Army and Marine commanders to assess the quality and utility of program products.
- Multispectral Adaptive Networked Tactical Imaging System (MANTIS).
  - Deliver SWIR sensor assemblies (from prime and alternate suppliers) for evaluation.
  - Complete Independent Lab Characterization/Field Tests on SWIR sensors.
  - Complete system design analyses.
  - Incorporate selected sensors in complete system design.

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- Independently evaluate multi-sensor imagery and processing capability.
- Complete prototype design.
- Deliver two MANTIS prototypes for evaluation.
- Complete independent lab/field tests of MANTIS prototypes.
- Transition to US Army/Objective Force Warrior and/or other transition partners.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Command and Control for CollaboRobotic Systems (C3RS) | 0.000   | 0.000   | 4.500   |

(U) The Command and Control for CollaboRobotic Systems (C3RS) effort develops integrated tactical planning and battle management systems for heterogeneous collections of unmanned platforms operating in urban environments. It employs a model-based control architecture to allow new platforms to enter the system at any time. Commanders register new platforms with the battle manager by submitting platform capability models (kinematics, maneuverability, endurance, payloads and communications links). C3RS provides a commanders' 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. It supplies computationally intensive decision aids, such as advanced 4D airspace and groundspace deconfliction tools, route planners and task/platform assignment algorithms. The technology presents mission status and future courses of action to commanders for collaborative adjudication. C3RS enables augmentation of low-footprint, rapidly deployable, easily sustainable human command structures with teams of machines operating together. It defines suitable roles for human command staffs charged with controlling squads of automated forces.

- (U) Program Plans:
- Select a baseline planning/control algorithm.
  - Develop hybrid state models of each vehicle.
  - 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.

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

- Not Applicable.



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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Information Integration Systems,<br>CCC-02  | 69.165  | 101.399 | 103.146   | 110.230 | 121.406 | 116.078               | 121.777 |

(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: Airborne Communications Node (ACN)/Adaptive Joint C4ISR Node Advanced Concept Technology Demonstrator (AJCN ACTD), the Secure Adaptive Waveforms (SAW) program, the Connectionless Networking (CN) program, the Next Generation (XG) program, the Advanced Speech Encoding (ASE) program, the Symbiotic Communications program, the Tera Hertz Operational Reachback (THOR)/Optical & RF Combined Link Experiment (ORCLE), the Space-Based Networking program, the Policy Based Network Management program, the Disruption Tolerant Networking program, the Network Centric Operations / Battle Command program, the Advanced Antenna Concepts program, the Navy Photonics program and the Command Post of the Future (CPOF) program.

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

|                                     |         |         |         |
|-------------------------------------|---------|---------|---------|
|                                     | FY 2003 | FY 2004 | FY 2005 |
| Airborne Comms Node (ACN)/AJCN ACTD | 20.102  | 4.300   | 0.000   |

(U) The Airborne Communications Node (ACN) program will enable an affordable, autonomous communications infrastructure that simultaneously provides assured communications, situational awareness and signals intelligence (SIGINT). 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 will be scalable such that payloads for various platforms can be constructed from a core set of common circuit boards and chassis.

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The ACN on an HAE platform will provide wide-area wireless communications and SIGINT services over the theater of operation for joint and multinational forces by establishing an early robust airborne infrastructure for intra-theater line-of-site (LOS) and reachback beyond line-of-site (BLOS) situations without the need for large in-theater assets. ACN will augment and enhance the battlefield communications infrastructure in order to adapt communications, situational awareness and SIGINT services to the flow of battle. Therefore, the ACN system needs to be adaptable, interoperable, robust, secure, and affordable within the size, weight and power constraints of the intended platforms. Additionally, the ACN architecture allows for the implementation of technologies that can securely adapt the various wireless systems (such as unattended ground sensors (UGS)) and command & control tiers that will exist in the future network centric battlesphere. The ACN system operational utility will be assessed by U.S. Joint Forces Command as part of a Joint 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 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.

(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).
- 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.
- Investigate technologies to provide secure waveforms.
- Investigate technologies to incorporate other systems (such as UGS) into the ACN architecture.
- Investigate technologies for advanced networking concepts, especially between dissimilar platforms.
- Integrate AJCN payloads on 2 Hunters and 2 NKC-135s.

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|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Secure Adaptive Waveforms (SAW) (formerly Adaptive Waveform (AW)) | 0.000   | 6.272   | 7.800   |

(U) The Secure Adaptive Waveforms (SAW) program, and the related PRZM program, will address lessons learned from the Airborne Communication Node (ACN) program concerning the need for secure communications waveforms. The SAW program will develop and demonstrate an adaptive waveform agile communications system that can change structure (frequency, 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 eliminate repeatability in transmissions by adapting the waveform randomly and forcing random network routing. In keeping with the multi-INT focus of the ACN program, secondary objectives of the SAW program include making the system capable of simultaneously supporting multiple missions, to include communications, SIGINT, radar, and electronic warfare.

(U) The goal of the Polarized Rotation Modulation (PRZM) Communications program is to develop new extremely high data rate, point-to-point, wireless communications using the PZRM communications concept which can be implemented at any wavelength – RF to visible – to exploit the presently unused polarization and rotation dimensions of radiation. The 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.

(U) Program Plans:

- Secure Adaptive Waveforms.
  - Initiate system design effort.
  - Initiate red team development of commercial off-the-shelf based exploitation receiver.

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- Analyze processing required and size terminal.
- Demonstrate and assess random network routing performance.
- Develop and demonstrate ability to generate single-mission dynamic waveforms in response to various stimuli (environment, quality of service, data type).
- Demonstrate performance against red team commercial off-the-shelf based exploitation receiver.
- 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 in field conditions at long range under operational conditions.

|                                | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------|---------|---------|---------|
| Connectionless Networking (CN) | 0.000   | 8.372   | 7.800   |

(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 such as 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

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intensive) routing, and availability of situational information to demonstrate a total energy savings of at least 100 times typical connection oriented network applications.

(U) Program Plans:

- Investigate specific technology requirements for each of the traditional wireless networks.
- Determine layer specific solutions.
- Investigate layer integrating approaches.
- Model acquisition and media access; network and transport design; and aggregate energy cost savings.
- Predict achievable performance improvement.
- Develop and evaluate candidate approaches for implementation complexity, on-board processor and memory capability/power, overhead, scalability and performance.

|                      | FY 2003 | FY 2004 | FY 2005 |
|----------------------|---------|---------|---------|
| Next Generation (XG) | 8.912   | 18.305  | 15.571  |

(U) The Next Generation (XG) program goals are to develop both the enabling technologies and system concepts to provide dramatic improvements in assured military communications in support of a full range of worldwide deployments through the dynamic redistribution of allocated spectrum along with novel waveforms. U.S. Forces face unique spectrum access issues in each country in which they operate, due to competing civilian or government users of national spectrum. These constraints must be reflected in all force planning and may preclude operation of critical systems. Coalition and allied operations are even more complex to manage, and may severely limit the U.S. ability to fully exploit its superiority and investment in information technology. The XG program approach is to develop the theoretical underpinnings for dynamic control of the spectrum, the technologies and subsystems that enable reallocation of the spectrum, and the system appliqué prototypes to demonstrate applicability to legacy and future DoD radio frequency emitters. The approach plans to investigate methods to leverage the technology base in microelectronics with new waveform and medium access and control protocol technologies to construct an integrated system. The proposed program goals are to develop, integrate, and evaluate the technology to enable equipment to automatically select spectrum and operating modes to both minimize disruption of existing users, and to ensure operation of U.S. systems. The result of the XG program will be to develop and demonstrate a set of standard dynamic spectrum adaption technologies for legacy and future emitter systems for joint service utility.

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- (U) Program Plans:
- Conduct CONUS and OCONUS spectrum usage analysis.
    - Analyze military bands during force exercises.
    - Analyze civilian band usage in a variety of locales (urban and rural settings).
    - Optimize 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.
  - Characterize next generation and RF component technology for inclusion into eventual demonstrator.

|                                | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------|---------|---------|---------|
| Advanced Speech Encoding (ASE) | 8.491   | 9.683   | 6.228   |

(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 vocoders. The program will compress speech to bit rates between 200 bps and 800 bps while producing speech quality at least as good as that produced by the current DoD standard and maintaining that quality and bit rate in noisy military environments. Reduction of voice communication bit rates will decrease the probability of detection of transmitted signals and also decrease the required transmit energy, hence increasing battery lifetime. ASE will reduce voice communication bit rates by directly measuring the glottal excitation function, using non-acoustic sensors allowing for a more accurate determination of the parameters needed for speech encoding. The ASE program will develop novel noise suppression and low-rate vocoding approaches that exploit the additional information provided by the noise-robust non-acoustic sensors. Reliable authentication of the speaker's identity using vocal excitation measurements will be investigated along with technologies for secured voice communications systems that are encrypted on the basis of the user's voice.

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- (U) Program Plans:
- Demonstrate encoded speech intelligibility for noisy environments that is equal to or better than that achieved with current systems for environments that are at least 40 dB quieter.
  - Demonstrate 200 - 800 bps vocoders with speech quality and intelligibility at least as good as the DoD standard vocoders using vocal excitation measurements to extract speech information content in noisy environments.
  - Investigate voice based authentication and encryption techniques.

|                          | FY 2003 | FY 2004 | FY 2005 |
|--------------------------|---------|---------|---------|
| Symbiotic Communications | 18.004  | 19.696  | 12.726  |

(U) Future combat systems increasingly rely on accurate intelligence preparation of the battlefield. This includes timely and accurate georegistration of all sensed data for precision weaponry on targets (including mobile targets). The single biggest error source that exists in the georegistration process is the lack of accurate knowledge of the terrain. Current national databases provide only coarse Level 1 data; Level 2 data will become available in the next several years. Neither Level 1 nor Level 2 data is sufficient to take full benefit of even current generation weapon accuracies, and the situation will worsen as weapons navigation and guidance systems improve at a faster pace. In order to overcome this, the Symbiotic Communications (SYCO) program will develop an airborne system that can generate, in real-time, Digital Terrain Elevation Data (DTED) with a precision commensurate with NIMA defined Level 4. This system will operate in all weather and passively. Additional attributes being explored include production of synthetic aperture radar (SAR) imagery and ground moving target indication (GMTI) to facilitate the detection, tracking and engagement of moving targets passively and in all weather conditions. Finally, exploration of techniques for using multiple frequencies to achieve enhanced spatial resolution leading to a potential DTED Level 5 precision will be conducted. Initial flight tests have been conducted that demonstrate the basic feasibility of SYCO operating modes and support studies of SYCO measurement phenomenology.

- (U) Program Plans:
- Conduct ground experiments for terrain scatter characterization.
  - Conduct system analyses and trade studies.
  - Develop hardware and conduct planning for early flight tests.
  - Investigate terrain classification using polarization, spatial and spectral diversity.



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- Investigate high-resolution passive imaging of emitters.
- Investigate potential platforms and begin hardware optimization process.
- Develop data processing architecture and algorithms for non-real time system.
- Conduct flight tests with non-real time system to validate algorithms.
- Demonstrate Digital Terrain Elevation Data (DTED) 3 with non-real-time processing of flight data.
- Develop real-time airborne system.
- Demonstrate DTED Level 4 with real-time processing of flight data.

|  | FY 2003 | FY 2004 | FY 2005 |
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| Tera Hertz Operational Reachback / Optical & RF Combined Link Experiment | 9.930   | 34.771  | 24.519  |

(U) The Tera Hertz Operational Reachback (THOR) program’s goals were to mature required technologies and credibly demonstrate a system able to provide a high data rate (internet-like) backbone to the tactical user whether airborne, terrestrial, or maritime. By focusing on the militarily unique need for a truly mobile and deployable high-data-rate infrastructure that extends access to existing commercial and military terrestrial fiber infrastructures, the Department’s vision of a “Global Grid” will be enabled by creating the high-data-rate nexus among the terrestrial, space, and air grids. This is expected to be accomplished by leveraging the commercial global optical fiber network, multi-quantum well retro-reflectors, and advances in optical phased array technology that have been motivated by directed energy applications. Together, these technologies enable the creation of a hybrid fiber-free space optical network extension. Gigabit-per-second connectivity and long-haul reachback to and between deployed theater command nodes, airborne, and maritime assets will be demonstrated in the final year of the program.

(U) In FY 2003, DARPA revamped the THOR program in order to properly demonstrate the advantages of free space optical (FSO) communications when simultaneously operating with more traditional and mature radio frequency (RF) communications techniques. This effort, the Optical & RF Combined Link Experiment (ORCLE) seeks to develop a combined RF & 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 environment. The central challenge is to enable optical communications bandwidth without giving up RF reliability and “all-weather” performance. This effort complements the capabilities in Mobile Free Space Optics under THOR. ORCLE will develop RF and FSO propagation channel analysis, coding techniques and modeling to include weather, atmospheric and aero-optics to

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provide the joint force commander assured high-data rate communications. The technical objective is to prototype and flight demonstrate hybrid FSO/RF air-to-air-to-ground links that combine the best attributes of both technologies and simulate hybrid network performance.

(U) Program Plans:

- During THOR, modeled route diversity, switching and self-correcting power of the networks as effective cloud mitigation strategy.
  - Determined that high bandwidth tip/tilt correction is effective for active tracking on both transmit and receive nodes.
  - Analyzed modeling retro reflectors used as Identified Friend or Foe which support link acquisition.
  - Developed initial multiple access receiver technology to reduce size and weight by sharing receiver optical hardware.
  - Developed non-mechanical beam steering to high performance levels that reduced size, weight and power.
  
- During ORCLE, 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 2003 | FY 2004 | FY 2005 |
|------------------------|---------|---------|---------|
| Space-Based Networking | 0.000   | 0.000   | 4.000   |

(U) The goal of the Space-Based Networking program is to provide a self-forming, self-healing mobile ad hoc network (MANET) in space between micro-satellites performing a space surveillance and awareness mission to/from other satellites and ground stations. This program leverages other DARPA efforts related to unfettered access to space and space control with a transition targeted to the Air Force. Significant technical obstacles include networking using high speed RF and optical links with high latencies due to distances of hundreds of kilometers, topology formation among fast moving nodes yet in predictable paths (orbits) or locations (ground-based), and the power, size, and weight constraints associated with space operations using micro-satellites.

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- (U) Program Plans:
- Develop network protocols for use in challenging space environments with high data rates.
  - Perform simulation analysis of candidate network protocols.
  - Perform a ground-based test of the network protocols using surrogate physical layer technology.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Policy Based Network Management (PBNM) | 0.000   | 0.000   | 2.000   |

(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.

- (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 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| Disruption Tolerant Networking (DTN) | 0.000   | 0.000   | 7.100   |

(U) Drawing upon technical challenges identified in specific programs such as ACN/AJCN and other non-ground based Mobile Ad-Hoc Network (MANET) based 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

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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.

(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.

|   | FY 2003 | FY 2004 | FY 2005 |
|---|---------|---------|---------|
| Network Centric Operations/Battle Command | 0.000   | 0.000   | 7.500   |

(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 centrality 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 centrality 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

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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 Units of Action 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).

(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 MANET-type self-forming, ad hoc, tactical networks incorporating, low probabilities of detection and intercepts, spectrum efficient waveforms; advanced information assurance; and 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 which 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.

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|                           | FY 2003 | FY 2004 | FY 2005 |
|---------------------------|---------|---------|---------|
| Advanced Antenna Concepts | 0.000   | 0.000   | 4.152   |

(U) The Micro-Aperture Circuit program 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 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. Non-Foster matching greatly reduces the transmitter power needed to deliver a prescribed amount of Radio Frequency (RF) to an electrically-small antenna. Application of advanced technology (Wide-band gap materials, such as SiN) offers the ability to fabricate devices that can effectively couple to very non-resonant antennas. DARPA will develop the basic technology, and then apply it to develop radios with wide bands of operation and very small physical size. 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.

(U) The Ultra-Fast Radar program 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 power spectrum 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.

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(U) Program Plans:

- **Micro Aperture Circuit:**
  - Develop negative inductors and capacitors in both grounded and floating configurations with antenna type devices capable of handling 5W or more of signal power.
  - Perform impedance matching to electrically-small antennas with optimal tradeoff among stability, frequency-response accuracy, bandwidth, and power handling ability.
  - Design and build an amplifier using a non-Foster matching circuit to deliver 5W or more to an electrically-small antenna.
  - Demonstrate the Micro-Aperture Circuit antenna concept in the development of radios with a wide band of operation and small physical size.
  
- **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.
  - 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 2003 | FY 2004 | FY 2005 |
|------------------------|---------|---------|---------|
| Navy Photonics Program | 0.000   | 0.000   | 3.750   |

(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

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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).

(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.

|                                   | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Command Post of the Future (CPOF) | 3.726   | 0.000   | 0.000   |

(U) The objective of the Command Post of the Future (CPOF) program was to improve the speed and quality of command decisions, more effectively disseminate command decisions, and reduce the number of staff members required to process and manage the information systems. Three important command functions were addressed to achieve this objective: 1) improved speed and quality of situation awareness; 2) improved speed of course of action (COA) development and selection; and 3) improved clarity of COA communication between commander and subordinates. For each of these command functions, CPOF developed technologies that leverage the expertise of the commander by exploiting and augmenting natural cognitive abilities. The key technologies developed were: (1) an integrated visualization environment for the commander and his staff; (2) a powerful and comprehensive human-computer interaction capability; (3) a robust collaborative communication environment for creating shared understanding among commanders and staff through both voice and visual interactions; (4) an integrated suite of systems to automate many of the lower level staff functions and automatically invoke and operate supporting, planning and analysis applications; and (5) a modular, portable suite of software components that can be quickly configured and tailored to various command environments (stationary and mobile), at different echelons of tactical command.



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- (U) Program Accomplishments:
- Completed the final experiments in cognitive principals of visualization, multi-modal interaction, collaborative planning and command decision-making.
  - Completed technology development of CPOF component technologies of dynamic visualization, multi-modal interfaces and collaborative planning.
  - Integrated final component technologies and knowledge bases into the final prototype commander’s mobile interactive display system, the BattleBoard; qualified system capabilities.
  - Conducted validation experiments with the Army’s Stryker Brigade Combat Team #2 at Ft. Lewis, and evaluate results for system improvements.
- (U) **Other Program Funding Summary Cost:**
- Not Applicable.

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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |         |         | R-1 ITEM NOMENCLATURE<br>Sensor and Guidance Technology<br>PE 0603762E, R-1 #44 |         |         |                       |         |
| COST (In Millions)  | FY 2003 | FY2004  | FY2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost   | 216.052 | 336.658 | 337.117   | 324.825 | 339.748 | 330.721               | 336.915 |
| Guidance Technology SGT-01  | 40.513  | 43.643  | 41.452  | 42.291  | 50.386  | 30.999                | 30.959  |
| Aerospace Surveillance Technology SGT-02  | 33.850  | 24.614  | 36.375  | 38.289  | 43.279  | 32.749                | 30.720  |
| Air Defense Initiative SGT-03   | 18.413  | 31.434  | 32.861  | 27.398  | 29.314  | 34.167                | 34.133  |
| Sensors and Exploitation Systems SGT-04   | 123.276 | 127.483 | 130.637   | 120.867 | 117.545 | 128.610               | 158.463 |
| Classified SGT-CLS  | 0.000   | 109.484 | 95.792  | 95.980  | 99.224  | 104.196               | 82.640  |

**(U) Mission Description:**

(U) The Sensors and Guidance Technology program element is budgeted in the Advanced Technology Development Budget Activity because it is developing the system oriented technologies necessary to enhance sensor and weapon system accuracy and capability to meet current and emerging threats. Four projects are funded in this program element: Guidance Technology, Aerospace Surveillance Technology, the Air Defense Initiative, and Sensors and Exploitation Systems.

(U) The Guidance Technology project will increase the ability of Global Positioning System (GPS) users to operate effectively in presence of enemy jamming; to increase the versatility of navigation systems applications by developing 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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(U) The Aerospace Surveillance Technology project funds sensor efforts that will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability and battle damage assessment. Timely surveillance of enemy territory under all weather conditions is critical to providing our forces with the tactical information needed to succeed in future wars. This operational surveillance capability must continue to perform during enemy efforts to deny and deceive the sensor systems, and operate, at times, in a covert manner. This project will exploit recent advances in multispectral target phenomenology, signal processing, low-power high-performance computing, and low-cost microelectronics to develop advanced surveillance and targeting systems. Surveillance is not an end to itself, but rather an enabler for force protection and precision strike. Therefore, a key component of this program is the development of a comprehensive sensor-to-shooter architecture.

(U) The Air Defense Initiative project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats. These technology developments are embodied in programs such as the Low-Cost Cruise Missile Defense (LCCMD), Global Eye, Affordable Large Array (ALA), RF MEMS Improvement, and the Integrated Sensor Is Structure (ISIS) programs.

(U) The Sensors and Exploitation Systems project funds development and demonstration of advanced sensors. Tools that extract and compile information from data provided by sensors are elements of the project. These efforts, along with those in Projects SGT-01, SGT-02 and SGT-03, provide warriors with situational awareness and precision target identification. The project is driven by four needs: (1) countering camouflage, concealment and deception (CC&D); (2) providing near-real-time, semi-automatic exploitation of wide-area moderate- and high- resolution imagery; (3) obtaining real-time, accurate Battle Damage Assessment (BDA); and (4) accomplishing robust, precise identification, precision fire control tracking and engagement of high value targets. These needs are addressed by the following programs: Advanced Exploitation Systems Technology, Network Centric Sensing and Engagement, Advanced Optical Sensor Technology, and Advanced Radar Sensor Technology.

|  |                       |                       |                      |
|--|-----------------------|-----------------------|----------------------|
| (U) <b><u>Program Change Summary:</u></b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
| Previous President's Budget                                    | 217.378               | 342.914               | 354.877              |
| Current President's Budget                                     | 216.052               | 336.658               | 337.117              |
| Total Adjustments  | -1.326                | -6.256                | -17.760              |

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|                                  | <u><b>FY 2003</b></u> | <u><b>FY 2004</b></u> |
|----------------------------------|-----------------------|-----------------------|
| Congressional program reductions | 0.000                 | -6.256                |
| Congressional increases          | 0.000                 | 0.000                 |
| Reprogrammings                   | 1.611                 | 0.000                 |
| SBIR/STTR transfer               | -0.285                | 0.000                 |

**(U) Change Summary Explanation:**

|         |   |
|---------|---|
| FY 2003 | Decrease reflects minor reprogramming with an offset for the SBIR transfer.                 |
| FY 2004 | Decrease reflects congressional undistributed reductions.                                   |
| FY 2005 | Decrease reflects a reduction in classified programs and minor repricing of other programs. |

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Guidance Technology SGT-01  | 40.513  | 43.643  | 41.452   | 42.291  | 50.386  | 30.999                | 30.959  |

(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; to apply the geolocation technologies/techniques to precision threat geolocation of short-dwell emitters or passive air defense systems; and to develop passive tagging capabilities.

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

|                                      |         |         |         |
|--------------------------------------|---------|---------|---------|
|                                      | FY 2003 | FY 2004 | FY 2005 |
| Global Positioning Experiments (GPX) | 9.134   | 4.000   | 0.000   |

(U) The Global Positioning Experiments (GPX) program increases 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 program addressed three key challenges. First, it demonstrated non-Keplerian orbit predictions of the APL and showed that only software modifications are needed for GPS user receivers. Second, it showed that the APL can accurately navigate using GPS satellites in the presence of jamming. A demonstration was conducted of a digital adaptive

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beamformer integrated with a pseudolite in a GPS jamming environment in both a full scale anechoic chamber and full scale field test, with greater than 45 dB nulls against up to six different jammers. Third, the program minimized the impact of APL technology on friendly, unmodified receivers and maximized interoperability through development of advanced waveforms, demonstration of an advanced beam shaping transmit antenna, precise management of the radiated power, and the associated command and control structure. The GPX program culminates with integrated demonstrations of APL or specialized signals capability in military exercises. In addition, APL methods have been investigated for exploitation of signals from satellites of opportunity for precision localization in the absence of GPS.

(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.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Advanced Tactical Targeting Technology (AT3) | 11.023  | 5.815   | 0.000   |

(U) The Advanced Tactical Targeting Technology (AT3) program is demonstrating a passive tactical targeting system against short-dwell emitters to improve lethal suppression of enemy air defenses (SEAD). The targeting system will negate emitter shutdown tactics now employed to defeat anti-radiation missiles (ARM) guidance, and thereby enable simplified ordnance inventories. The goal is generation and distribution of 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 will accomplish this by widely deploying emitter collection packages hosted on existing airborne platforms, including combat aircraft. AT3 will integrate 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 focuses 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.

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- (U) Program Plans:
- Complete and analyze results from real-time flight tests at western test ranges to ensure that program goals were met.
  - Demonstrate AT3 technologies and capabilities.
  - Support transition to Air Force and Navy.

|        | FY 2003 | FY 2004 | FY 2005 |
|--------|---------|---------|---------|
| MEDUSA | 18.363  | 26.612  | 23.952  |

(U) The Multifunction Electro-Optics for Defense of U.S. Aircraft (MEDUSA) program will develop the technologies and systems to give the U.S. air dominance at low altitude and at night. This program will develop the technologies to leap-frog reactive end-game countermeasures and enable increased threat warning times, denial of launch, and put EO-IR air defense threats at risk. MEDUSA is a three-part technology program: (1) conduct phenomenological measurements and develop countermeasures and target classification/identification techniques; (2) develop critical component technologies such as high power IR laser sources, advanced IR detectors, and fibers for high power IR transmission; and (3) develop and demonstrate an end-to-end MEDUSA system.

- (U) Program Plans:
- Develop and evaluate MEDUSA countermeasure and classification techniques and conduct phenomenological measurements.
  - Fabricate and evaluate critical component technologies.
  - Develop MEDUSA system designs.
  - Build and field test a MEDUSA breadboard design against realistic targets and environments.

|                     | FY 2003 | FY 2004 | FY 2005 |
|---------------------|---------|---------|---------|
| Advanced Gyroscopes | 0.000   | 5.216   | 5.500   |

(U) The Advanced Gyroscopes program will develop very high-accuracy gyroscopes for extremely precise navigation, with a goal of reducing gyroscopes noise error to  $10^{-5}$  degree/hour or less. This technological leap will enable more robust operations of several magnitudes – from



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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.

- (U) Program Plans:
- Evaluate feasibility of underlying approach in the laboratory.
  - Develop breadboard gyroscopes and test for ultra-low noise and angle random walk.

|                                       | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------------|---------|---------|---------|
| Precision Inertial Navigation Systems | 1.993   | 2.000   | 7.000   |

(U) The Microelectromechanical Sensor Inertial Navigation System (MEMS INS) program is improving the silicon based, inertial sensors (gyros and accelerometers) developed in the MEMS technology program and integrate them with navigation software into a low power, small, lightweight, low cost, tactical grade (1.0 degree per hour to 10 degrees per hour drift rate) INS. In addition to handheld applications, the MEMS INS will be generic for insertion/embedding into other military systems.

(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.

- (U) Program Plans:
- Delivered MEMS inertial measurement unit to the DoD.
  - Completed field demonstration of MEMS INS navigation capabilities.
  - Investigated novel INS designs for very large structures that exploit large baseline separation.
  - Investigated MEMS and meso suitability to space applications.

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- Develop and demonstrate inertial navigation system with positional bias drift rate below 5 meters/hour.
- Development of 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.

|                                       | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------------|---------|---------|---------|
| Navigation Via Signals of Opportunity | 0.000   | 0.000   | 5.000   |

(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 jamming or other effects. An outgrowth of the GPX program, the NAVSOPP program will develop the procedures and technologies for geolocation of stationary and mobile platforms via exploitation signals of opportunity or specialized signals from satellite, airborne, and terrestrial assets. The NAVSOPP is a two part program: (1) Cataloging and assessment of potential exploitable signals followed by analysis and performance modeling and hardware-based concept validation (2) Design and test of a prototype receiver(s) and algorithms for geolocation using the signals of opportunity. This would include demonstration of a non-form/fit functional prototype system.

(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 system.
- Field test and demonstrate the functional prototype in realistic environments.

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

- Not Applicable.

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005 | FY 2006  | FY 2007 | FY 2008               | FY 2009 |
| Aerospace Surveillance Technology SGT-02  | 33.850  | 24.614  | 36.375  | 38.289   | 43.279  | 32.749                | 30.720  |

**(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.

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

|                                |         |         |         |
|--------------------------------|---------|---------|---------|
|                                | FY 2003 | FY 2004 | FY 2005 |
| Counter-Underground Facilities | 14.110  | 14.614  | 18.000  |

(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 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 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,

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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, 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 techniques as necessary to meet the data-localization and data-exfiltration requirements.

(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.
- Demonstrate functional prototype of multi-mode/multi-node ground sensor system, using clutter-limited sensors.
- Demonstrate rapid, airborne surveillance and mapping of UGF structures.
- Develop 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.
- Develop multi-sensor characterization tool for planning and targeting.

|                                      | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| Digital Radio Frequency Tags (DRAFT) | 10.000  | 8.000   | 3.375   |

(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

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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.

(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.

|                    | FY 2003 | FY 2004 | FY 2005 |
|--------------------|---------|---------|---------|
| Rescue Transponder | 0.000   | 2.000   | 6.000   |

(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, wearable, rugged, individual-worn transponder that provides a call for help to friendly forces that has a signal with substantial LPD margin, so that enemies are not able to exploit the signal to capture or detain friendly forces isolated on the battlefield or in a perilous location. The RT system will operate over ranges that enable rescue forces or surveillance systems to receive its signals while avoiding hostile fire or detection. It will support accurate localization by rescue forces, and permit transmission of identifying, authenticating, and status information.

(U) Program Plans

- Develop small wearable tags which enable the user to be identified and localized by airborne or advantaged receivers with a very LPD signal of the wearer's identity, location and status.

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- 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 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| Threat Characterization of Buildings | 0.000   | 0.000   | 5.000   |

(U) This program will develop technologies and systems for new surveillance capabilities of buildings. It will develop and demonstrate wall-penetrating multi-static Doppler radar for stand-off mapping of building layout (via long-term integration of human motion) and for localization of enemy forces immediately upon entering buildings (via portable radar “flashlights”). It will also demonstrate technologies to monitor the integrity of building envelopes, to identify a breach of previously sealed/secured buildings and to identify previously hidden connections between buildings; approaches include pressure and power-line monitoring as well as the use of tracer gases.

- (U) Program Plans:
- Evaluate candidate designs for wall-penetrating Doppler radar.
  - Evaluate candidate technical approaches for monitoring building envelope integrity.
  - Prove feasibility in lab on sub-scale models.
  - Design, build, and test prototypes for use in full-scale demonstration.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Surveillance and Threat Neutralization in Urban Environments | 0.000   | 0.000   | 4.000   |

(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

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remote-control circuits; multi-static radars for standoff identifications of shrapnel-packed bombs; detection of anomalies in gait, heartbeat, and breathing; 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.

- (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 2003 | FY 2004 | FY 2005 |
|----------------------------|---------|---------|---------|
| Large Millimeter Telescope | 9.740   | 0.000   | 0.000   |

(U) The Large Millimeter Wave Telescope (LMT) program was the U.S.-complement to a coordinated U.S.-Mexico project. The DARPA program provided technology assessments for design, systems integration and technology-leading metrology for a 50-meter aperture, fully steerable millimeter wave radio telescope. The fully developed telescope features a sophisticated laser metrology system to maintain precise alignment of the optics, and real-time closed loop adaptive control to maintain a near-perfect parabolic surface at all pointing angles and under most environmental conditions.

- (U) Program Accomplishments:
- Continued fabrication of metrology panel and surface.
  - Continued development of antenna holography system and precision pointing.
  - Initiated system integration for construction of base line telescope.
  - Integrated the antenna panels and metrology system into the telescope.



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

- Not Applicable.

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Air Defense Initiative SGT-03   | 18.413  | 31.434  | 32.861   | 27.398  | 29.314  | 34.167                | 34.133  |

(U) **Mission Description:**

(U) This project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats. These technology developments are embodied in the following programs: Low-Cost Cruise Missile Defense (LCCMD); Affordable Large Array (ALA); Global Eye; RF MEMS Improvement; and Integrated Sensor Is Structure (ISIS).

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

|   |         |         |         |
|---|---------|---------|---------|
|   | FY 2003 | FY 2004 | FY 2005 |
| Low-Cost Cruise Missile Defense (LCCMD) | 8.265   | 12.129  | 10.000  |

(U) The LCCMD program will design, develop, demonstrate and transition an affordable electronically scanned array (ESA) seeker for use on a missile interceptor system to defeat unsophisticated air vehicles. Unsophisticated air vehicles are affordable, can be procured in large numbers to overwhelm U.S. defenses and provide a credible long-term threat to both civilian population centers and military targets. To reduce the cost of defending against such threats, it is crucial to reduce the cost of the guidance and control sections of defensive weapons. The LCCMD program will enable this through analyses, laboratory testing and field-testing of an all-weather seeker costing less than fifty thousand dollars in production. The program has pursued six novel concepts and is presently focused on the maturation and demonstration of radar seeker solutions employing active ESA concepts using low cost single-chip transmit/receive modules. In addition, the program is developing low-cost surveillance systems to provide the warning/cue for such interceptors.

(U) Program Plans:

- Build and test active ESA antenna.
- Fabricate seeker back-end and integrate with ESA seeker antenna in preparation for ground or flight test.
- Conduct ground or flight test (in collaboration with service transition partner).

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- Initiate systems design for low-cost surveillance approaches to provide cue for low-cost interceptors.
- Conduct field measurements to support performance characterization of surveillance systems.
- Design and build prototype surveillance system for a small-scale feasibility demonstration.

|                              | FY 2003 | FY 2004 | FY 2005 |
|------------------------------|---------|---------|---------|
| Affordable Large Array (ALA) | 4.583   | 2.000   | 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 overall objective of the program was to develop and demonstrate these transceivers for population of very large, lightweight, active electronically scanned radars that could meet the future DoD needs of a wide variety of radar systems. Low-power, high efficiency, lightweight transceiver module technologies offer the important benefits of being able to operate reliably without the need for liquid or forced air cooling. 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. It may also be possible to replace hard-wired beam steering control and RF manifolds by optical and RF space-fed configurations, which will result in additional significant savings in cost and weight.

(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.

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|                                       | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------------|---------|---------|---------|
| Integrated Sensor Is Structure (ISIS) | 0.000   | 8.800   | 14.000  |

(U) The ISIS program (previously called “Lightfoot Radar”) will develop antenna technologies that transform the transportability of sensor and communications systems. Program goals are the reduction in total system weight, prime power consumption, fuel requirements, and personnel requirements, so as to enable an unmanned airborne surveillance and communication system that provides persistent monitoring of all airborne and ground-based battlefield targets and simultaneously meets battlefield comms needs, over one full year of continuous operation. It is anticipated that the unprecedented power-aperture necessary to meet the program goals can only be provided by fully integrating the sensor into a station-keeping airship platform – hence, the name ISIS: “Integrated Sensor Is the Structure”.

(U) Program Plans:

- Develop large-scale signal distribution and single chip electronics technologies to enable extremely large low-power active array antennas.
- Develop lightweight tensional structures and dynamic calibration techniques to enable semi-flexible active array antennas.
- Develop terahertz sources and signal processing techniques to enable hand-held sensors.
- Develop discrete switches or bi-state materials to enable steerable reflect arrays.
- Develop passive RF tags or nano-particles to be remotely queried by ISIS.
- Develop conceptual designs that meet ISIS program goals.
- Develop and test required technologies, including large-scale signal distribution, low-power-density single-chip electronics, light-weight tensional structures, dynamic calibration techniques.
- Build and demonstrate a prototype ISIS system or sub-system.

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|                     | FY 2003 | FY 2004 | FY 2005 |
|---------------------|---------|---------|---------|
| RF MEMS Improvement | 4.682   | 8.505   | 8.861   |

(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.

(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.

|            | FY 2003 | FY 2004 | FY 2005 |
|------------|---------|---------|---------|
| Global Eye | 0.883   | 0.000   | 0.000   |

(U) The Global Eye program developed lightweight low-cost electronically scanned array (ESA) technology capable of supporting multiple simultaneous radar modes and frequencies through the use of mono-static or pseudo-mono-static apertures operating in a simultaneous transmit and receive (STAR) mode. Platforms outfitted with this capability provide lower cost continuous air and ground surveillance of low intensity areas such as no-fly zones and peacekeeping areas. Such capability could supplement traditional AWACS and JSTARS and potentially reduce the requirement to forward base large numbers of such aircraft for these purposes. The key technologies developed included an X-band proof-of-concept ESA risk reduction array capable of supporting up to a 100% transmit duty factor using currently available transmit/receive (T/R) modules, beam polarization diversity, and advanced mode control/interleaving algorithms.

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- (U) Program Plans:
  - Completed the building and testing of demo array.
  - Demonstrated pseudo-mono-static ESA operation using a 1 sq ft risk reduction array and a separate X-band receive aperture.
  - Evaluated its ability to support multiple-mode, multiple-frequency, and radar operation during ground testing with a Moving Target Simulator (MTS) and a mechanically scanned receive aperture.
  
- (U) **Other Program Funding Summary Cost:**
  - Not Applicable.

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Sensors and Exploitation Systems,<br>SGT-04   | 123.276 | 127.483 | 130.637  | 120.867 | 117.545 | 128.610               | 158.463 |

(U) **Mission Description:**

(U) The Sensors and Exploitation Systems project develops and demonstrates advanced sensors, and exploitation technologies. These efforts, along with those in Projects SGT-01, SGT-02 and SGT-03, provide warriors with situational awareness and precision target identification. The project is driven by four needs: (1) countering camouflage, concealment and deception (CC&D) of mobile ground targets; (2) providing near-real-time, semi-automatic exploitation of wide-area moderate- and high- resolution imagery; (3) obtaining real-time, accurate battle damage assessment; and (4) accomplishing robust, precise identification, precision fire control tracking and engagement of high value targets. These needs are addressed by the following programs: Advanced Exploitation Systems Technology, Network Centric Sensing and Engagement, Advanced Optical Sensor Technology, and Advanced Radar Sensor Technology.

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

|  |         |         |         |
|--|---------|---------|---------|
|  | FY 2003 | FY 2004 | FY 2005 |
| Advanced Exploitation Systems Technology | 32.500  | 47.004  | 47.998  |

(U) The Advanced Exploitation Systems Technology program develops systematic means to interpret and exploit sensor data, semi-autonomously. 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. It applies advanced signal processing and machine vision to leverage advances in sensor capabilities. Initiatives in this program include the following:

- Frequency-Diverse Spatial/Spectral Sensor Exploitation develops methods to better utilize advanced sensors. The initiative encompasses high-resolution multispectral, multipolarization, radio frequency, electro-optical (EO) and active optical sensors. The program



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significantly improves mapping, terrain characterization, target detection and situational awareness. It explores applications for both medium- and high-altitude deployment. This technology 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. They apply 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 to support robotic and manned maneuver forces.

- The National/Tactical Exploitation (NTEX) initiative develops technologies to locate and identify enemy air defense units. It uses multi-source imagery and data from both National reconnaissance systems and tactical sensor assets. Under a DARPA Memorandum of Agreement with the National Imagery and Mapping Agency (NIMA), the project places researchers in facilities with access to real data and analysts managed by the “Geospatial Intelligence Advancement Testbed” project at NIMA. They 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. It demonstrates increased capability to model, detect, and locate air defense targets and surface threats, including those that have been denied, modified or have not yet been modeled.
- Video Verification and Identification (VIVID) (formerly Video Exploitation Technology (VET)) develops technology to automate airborne video exploitation. Program products support precision strike operations and urban surveillance. VIVID enables the handoff of targets between wide area coverage Intelligence, Surveillance, and Reconnaissance systems and local video surveillance platforms. It investigates techniques for precision target identification in video. These include fingerprinting techniques and related technology to permit reacquiring previously-seen vehicles. The program also features techniques enabling video sensors to autonomously track people and multiple vehicular targets through dense traffic in military areas of operation overseas. It supports target area searches for non-combatants and “no-strike” entities, to mitigate collateral damage. VIVID technologies significantly advance the capabilities of video surveillance for a number of military missions, including counter-terrorism and military operations in foreign urban areas.
- 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

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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 initiative (E3D) 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. The Target Recognition module investigates the object recognition process. The Target Acquisition module develops target acquisition methods based on search of a local 3-D volume for possible targets. The Modeling module enhances identification methods based on detailed shape analysis. The resulting software tools are designed to be integrated into a number of ground stations to receive 3-D sensor data.
  - The Dynamic Tactical Targeting (DTT) initiative is developing sensor control and data fusion technologies to enable a tactically responsive warfighter-managed targeting process. Recent events reinforce the need for warfighter-managed technologies that 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: (a) leverages existing National/Theater intelligence, surveillance and reconnaissance (ISR) processes for timely extraction of critical data; (b) fuses organic sensor data with ISR data from all sources to enable multi-scale estimation of target location, identity and activity; (c) dynamically tasks standoff, organic, and embedded sensors to fill ISR coverage gaps and provide relevant sensor observation in areas of tactical interest; and (d) processes and manages the large volume of data produced by all these sensors in time to give shooters the information required to prosecute TSTs.
- (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 these signatures.

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- Design, develop and evaluate brassboard sensor hardware and evaluate system performance under controlled environments.
- Design, develop and evaluate form, fit and function sensor hardware.
- Integrate on aircraft and evaluate performance in flight test over realistic targets and large clutter sets.
  
- 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 a few sensor views, then locate and recognize 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 otherwise be missed by analysts, in a real-world practical problem.
  
- 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 people that could become 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 collected advanced laser radar (LADAR) data for research and development modules.
  - Acquire and refine 3-D models of potential target vehicles.

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- 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.
- 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 4D registration of multiple tracks that is fast enough to enable continuous tracking of multiple targets.
  - Develop information fusion methods and the capability to plan and re-plan 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 for use in field demonstrations.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Network Centric Sensing and Engagement | 39.542  | 29.891  | 24.100  |

(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 treats a group of sensors as a system. It leverages networked intercommunication to enable system performance much 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.

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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) (formerly Micro-Sensor Fields) initiative develops low-cost, lightweight micro-sensors for area reconnaissance and perimeter monitoring. It will support warfighter operations in complex and urban terrain. Its sensors operate in both monostatic and bistatic modes. The program emphasizes low-power and long-life detection and discrimination capabilities. Enabling technologies include ultra-wide band radar, advanced sensor power management and generation, and low-power computing. The effort is developing robust techniques for rapid geolocation and data exfiltration from sensors. It demonstrates technology for visualizing networks and fields of micro sensors and exploiting and fusing data received from them. CLENS enables force protection with greatly reduced manning. It supports monitoring of borders and critical CONUS sites, long-duration covert monitoring of target sites such as terrorist camps, and deep-strike engagement of mobile targets. It has broad application in support of comprehensive intelligence, surveillance, and reconnaissance for situational awareness. CLENS enables persistent sensing of dismounted combatants in the toughest of environments, such as forested areas.
- 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) reconfigurable in fractions of a second; (2) wideband capacity (10+Mbit/s) on demand; (3) near zero (2ms) latency for high priority messages; (4) complete interoperable with Link 16; and (5) inexpensive to procure and to install. 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.

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- The Affordable Moving Surface Target Engagement (AMSTE) initiative develops technologies required to network existing radar sensors. Of particular interest are tactical and theater ground moving target indication (GMTI) sensors. The program enables affordable, all-weather, precision negation of moving surface targets (both land- and sea-based), from stand-off ranges. Precise cueing from netted GMTI sensors will reduce the complexity and thus the cost of precision munitions. AMSTE demonstrates in-flight midcourse and terminal guidance to weapons resulting in accuracy an order of magnitude better than current systems against moving targets. The program also demonstrates unaided precision grid locking techniques and low-cost weapon data links. AMSTE advanced multi-platform tracking algorithms deliver precise and long-duration, high-confidence track purity using moving target feature phenomenology for track maintenance.
  - 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.
- (U) Program Plans:
- Camouflaged Long Endurance Nano-Sensors.
    - Develop breadboard ultra-wide band radar micro-sensor for dismount detection and tracking.
    - Design receiver node to process micro-sensor detects into tracks and exfiltrate 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 brass-board design and fabrication.
    - Complete brass-board TTNT flight experiments and demonstrations at large scale.
  - Affordable Moving Surface Target Engagement.
    - Complete development and fabrication of the final field experiment system for demonstration in an integrated operational environment.

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- Demonstrate a full AMSTE weapons delivery capability with advanced target track maintenance in live weapons drops with moving targets.
  
- 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.

|                                    | FY 2003 | FY 2004 | FY 2005 |
|------------------------------------|---------|---------|---------|
| Advanced Optical Sensor Technology | 18.992  | 21.464  | 26.519  |

(U) The Advanced Optical Sensor Technology Program develops technology to significantly improve 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 air vehicle demonstrations of standoff 3-D Ladder 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. The results 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 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 system will

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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. These capabilities will be provided 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 program is to provide a proof-of-concept for operation at tactically relevant high altitudes and at long ground ranges. A secondary goal of the program is to demonstrate single-view ground moving target indication (GMTI) with targeting quality absolute accuracy in range and cross-range when operating in a coherent, real-aperture mode.

- Eyeball is developing novel methods for precision target identification (ID) of moving and stationary tactical targets from standoff platforms. It employs electro-optical sensors working in conjunction with air and space-based radar Ground Moving Target Indication (GMTI) and Synthetic Aperture Radar (SAR) sensors. Future radar assets are expected to be capable of performing target detection, location and tracking, and even some forms of target classification. However, GMTI-SAR target ID performance is expected to remain constrained by radar and signature limitations. The Eyeball sensor will exploit the benefits of combining spatial, spectral and polarimetric signatures from sparse or filled apertures to enable real-time precision ID of critical tactical targets. In the concept of operations, a GMTI-SAR platform will hand-off moving and stationary target location information to the Eyeball sensor. Eyeball will identify the target at standoff range and return the target ID to the radar for track-file association. Through episodic revisits, Eyeball will enable the GMTI-SAR platform to maintain continuous track of the tactical target. The program will deliver the necessary understanding of what is required in terms of combined spatial, spectral, and polarimetric signatures and resolution trades across the sensing domains to realize target-quality ID performance.
  - The Fogcutter initiative explores novel methods for optical imaging in the presence of fog, clouds, and other aerosols. The objective is Visual Flight Rules (VFR)-like performance for air vehicles in Instrument Flight Rules (IFR) conditions. Initial technology demonstrations will take place in a maritime environment.
- (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.



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- 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.
  - 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.
  
- Eyeball
  - Conduct additional ground-based experiments at North Oscura Peak to complete the data collection.
  - Design an airborne sensor system and evaluate utility and concepts of operation.
  
- Fogcutter
  - Develop imaging technologies to detect optical signals in strong scattering and absorptive environments, such as clouds.
  - Develop techniques and technologies for false alarm and clutter mitigation.
  - Collect data for characterization of targets operating in obscured settings.
  - Conduct and evaluate phenomenology, modeling and architecture/systems trades.

|                                  | FY 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Advanced Radar Sensor Technology | 32.242  | 29.124  | 32.020  |

(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

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exploiting emergent and novel radar sensing technology and phenomenology. Key elements are advancements in ultra-wide band, biostatics, 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 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; and situations where camouflage, decoys and countermeasures must be overcome. Initiatives in this program include the following:

- The Wide Area All Terrain Change Indication Technologies (WATCH-IT) initiative is developing real-time VHF/UHF synthetic aperture radar (SAR) automatic change detection and discrimination technologies. These provide the commander with rapid, robust detection of threat systems in the open, under camouflage and in foliage. WATCH-IT features discrimination algorithms to 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 the high altitude unmanned air vehicle (UAV). It will demonstrate high area-coverage rates with few false alarms. 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 enables rejection of confusers (i.e., decoys, relocated vehicles that are not of military significance), and thus greatly improves target classification/identification.
- 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. It is developing a Foliage Penetration (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 km against dismounted troops moving in forested areas. It employs adaptive antenna processing and innovative radar waveforms to overcome radio frequency interference and electronic countermeasures in hostile electromagnetic environments. In FY04 and beyond, this program will be funded in PE 0603764E, Project LNW-03.

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- 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 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 Counter Camouflage, Concealment and Deception (Counter CC&D) program significantly enhances the commander’s capability to detect and track targets hidden under foliage and camouflage. The program is validating Foliage Penetration (FOPEN) target detection and false alarm rejection capabilities. A FOPEN synthetic aperture radar (SAR), developed for demonstration on a manned RC-12 aircraft, provides inputs via tactical data links for ground image exploitation. A Ground Control and Display Subsystem provides real-time, remote operation of the FOPEN SAR, Automatic Target Detection and Cueing, and a Common Imagery Ground/Surface System-compliant exploitation interface. The program is developing advanced change detection and three-dimensional tomographic imaging algorithms. Program-developed techniques characterize terrain cover and the bald-earth topography in support of Future Combat Systems.
- The Generation After Next Airborne Surveillance Radar (GAN) initiative develops 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 overcomes challenges associated with low revisit rates, limited concurrency of modes, low power efficiency, low resolution, and difficult sensor management problems. The program develops techniques to demonstrate critical concepts, including: (1) very high revisit rates; (2) high concurrency of modes (e.g., simultaneous SAR and GMTI, with potentially every pulse used for every function); (3) high power efficiency (again, every pulse used for every function); (4) high resolution (due to tomographic processing of wide angles); and (5) potentially straightforward sensor management (sensor management becomes a post-processing decision rather than a pre-sensing decision). GAN is demonstrating that these concepts, in turn, offer significant improvements in detection, tracking, and ID. By

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supporting several modes on the aperture concurrently, GAN offers 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. It 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. It provides commanders with characterization and targeting information for facilities, vehicles and dismounted targets. It also delivers tactical situation awareness, and supports strategic indication and warning.

(U) Program Plans:

- Wide Area All Terrain Change Indication Technologies.
  - 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 Yuma, AZ.
  - Assess alternative change detection algorithms to determine robustness to data variations, computational requirements, and other factors impacting suitability for implementing on a UAV.
  - Quantify 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 ATD system. Demonstrate real-time on-board change detection and high-speed discrimination processing in the ground station.
  - Develop system specification for a fully integrated WATCH-IT system.
  - Develop, integrate, install and flight test the WATCH-IT on a manned or unmanned aircraft.
  
- Foliage Penetration (FOPEN) Reconnaissance, Surveillance, Tracking and Engagement Radar.
  - Demonstrate detection of slowly moving ground targets in foliage by rotorcraft-mounted GMTI radars through measurements, simulations and analyses.
  - Design, assess, and evaluate a brassboard FORESTER hardware system.

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- Design, assess, and evaluate a form-fit-and-function FORESTER hardware system for rotorcraft installation.
- 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.
  
- Knowledge Aided Sensor Signal Processing and Expert Reasoning.
  - Develop advanced expert-reasoning algorithms using real and simulated data sets in non-real-time (offline) and real-time modes.
  - Develop real-time, high-dimensionality KASSPER software.
  - Conduct off-line KASSPER Constant False Alarm Rate & Radar (CFAR) demonstration.
  - Define 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.
  
- Counter Camouflage, Concealment and Deception.
  - Collect and assess data to support terrain characterization under foliage.
  - Support the Air Force’s Targets Under Trees (TUT) initiative.
  
- Generation After Next Airborne Surveillance Radar.
  - Develop the generation-after-next standoff airborne ISR radar.
  - Develop missions and concepts of operation to evaluate GAN sensor concepts against.
  - 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 appropriate field activities.
  
- 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 system’s capability against militarily significant targets.

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

- Not Applicable.

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| COST (In Millions)  | FY 2003 | FY2004 | FY2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost   | 26.164  | 13.751 | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |
| Advanced Ship-Sensor Systems, MRN-02  | 26.164  | 13.751 | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |

(U) **Mission Description:**

(U) The objective of the Marine Technology program is to identify, develop and rapidly mature critical advanced technologies and system concepts for maritime applications that support the following goals: 1) maintenance of U.S. naval force access to the littoral by countering the threat created by the worldwide spread of increasingly sophisticated technology; 2) enhancement of the ability of U.S. naval forces to interrogate and dominate the maritime battlespace, particularly in the littoral arena; 3) advances in the ability of U.S. naval assets to conduct operations as a seamlessly networked and integrated theater level force; and 4) improved power projection capabilities of U.S. naval forces, particularly with respect to their ability to influence the land battle. Proliferating threats such as modern cruise missile technology, commercially available overhead surveillance, advanced undersea mine capabilities, and modern, quiet diesel/electric submarines, pose major challenges for operations in the restricted water, near-shore regimes that are of growing importance to U.S. strategic considerations, necessitating continued development of increasingly affordable far-term solutions for enhancing the operating capability and survivability margins of U.S. naval forces in the littoral. This program element funds the Advanced Ship-Sensor Systems project (MRN-02), comprised of the following programs: the Robust Passive Sonar (RPS) program; the Loki Systems Development Program/the Mobile Undersea Distributed Systems; the Undersea Littoral Warfare thrust which includes the Littoral Force Architecture and the Submarine Design Studies (formerly known as the Piranha effort), and the Smart Actuators and Marine Projects Demonstration effort. This project draws to an end in FY 2004. Programs traditionally budgeted in this project will instead be budgeted in PE 0603766E, Project NET-02 to better reflect today's emphasis on network centric warfare.



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

|                            | FY 2003 | FY 2004 | FY 2005 |
|----------------------------|---------|---------|---------|
| Robust Passive Sonar (RPS) | 14.567  | 9.095   | 0.000   |

(U) The Robust Passive Sonar (RPS) program is developing innovative, adaptive signal processing algorithms for passive submarine and surface ship towed arrays that suppress the acoustic interference generated by surface shipping and increase the detectability of threat submarines. At the lower acoustic frequencies, shipping interference represents the primary noise background limiting the performance of existing sonar systems in littoral areas. Precise notching of shipping interference could result in net system performance gains of 10-20 dB, and the algorithms and array geometries used to accomplish this will dictate future tactical sonar designs. The program has successfully collected high quality, mobile, multi-line, towed array acoustic and ancillary data and utilized this data to develop and assess signal processing architectures and algorithms. Initial performance assessments indicate significant suppression of acoustic interference is achievable.

(U) **Program Plans:**

- Complete processing architecture and algorithms development.
- Evaluate algorithms in laboratory testing.
- Complete system trade studies for alternative acoustic aperture concepts.

|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Loki / Mobile Undersea Distributed Systems | 3.945   | 0.000   | 0.000   |

(U) The Loki program evaluated technologies that had the potential to enable a revolutionary “fighter-like” submersible to counter the asymmetric threat posed by diesel submarines and other forces operating in the littorals. Loki examined two major technology component elements: The Vortex Combustor propulsion technology and the Loki Systems technology development efforts. Objectives included: 1) the development of an energy-dense air independent underwater power source as a potential propulsion system for an underwater fighter, and 2) the investigation and development of detailed concepts of supporting systems and potential hull forms necessary for the operational viability of a

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future underwater fighter. Preliminary results from the Loki and other studies, and the Vortex Combustor testing indicated that while the capabilities of the Loki vehicle may be revolutionary, they could be best obtained by distributing them throughout a networked system. Therefore, the investment in the Loki program transitioned in FY 2003 into the Mobile Undersea Distributed Systems (MUDS) program. The truly network centric MUDS program continues in PE 0603766E, Project NET-02 in FY 2004.

- (U) Program Accomplishments:
- Vortex Combustor (VC).
    - Conducted several test firing of the Vortex Combustor system.
    - Conducted analysis and performance evaluation.
  - Loki Systems Development/Mobile Undersea Distributed Systems.
    - Conducted concept of operations and military utility studies.
    - Initiated system structural materials explorations.
    - Completed studies indicating that a distributed system concept known as the Mobile Undersea Distributed System (MUDS) was the most optimized way to achieve the goal of the Loki program.
    - Initiated concept of operations and military utility studies for the MUDS concept.

|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Undersea Littoral Warfare (ULW) | 7.652   | 4.656   | 0.000   |

(U) The ULW program is developing approaches to undersea warfare that will revolutionize the ability to classify and identify underwater objects such as mines. The ULW program seeks to provide the Navy with technologies that will allow U.S. submarines to dominate in the littoral battlespace and transform the submarine's role in littoral warfare. In doing so, the program will investigate: technologies and demonstrations for locating and tracking maritime targets of interest; innovative networking; sensor and array technologies; technologies and demonstrations enabling unique weapons or payload concepts for potential deployment on submarines and other undersea vehicles. The following specific efforts are included.

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(U) Two studies examine both platform specific and the overall architecture necessary for current and future maritime systems to effectively operate. These studies (originally conceived as part of the Piranha effort) are the Littoral Force Architecture Study and the Submarine Design Study. The Littoral Force Architecture Study is an effort with the Navy to identify the individual and collective technologies necessary for successful operation in areas defended by forces ashore, by mines, submarines, small craft and anti-ship missiles, to define the desirable and achievable performance characteristics of various manned and unmanned systems usable in a Littoral Naval Force.

(U) The forward-based littoral Naval force will enable unimpeded joint force access through a contested littoral in less than 96 hours. The Submarine Design Study explores innovative future submarine design concepts predicated on a distributed pump-and-jet propulsion (DPJPS) system concept, with the goals of reduced (50%) displacement, acquisition cost and equivalent operational performance relative to VIRGINIA Class.

(U) The Smart Actuators and Marine ProjectS demonstratiON (SAMPSON) effort is a systems level demonstration of the application of Smart Materials/Structures to enable vehicles to change the way they operate and take on new missions. By employing this technology aircraft will achieve dramatically improved range, maneuverability and enhanced survivability, and marine vehicle turbo-machinery will operate with improved performance characteristics. SAMPSON core technology efforts have produced several new concepts and designs for high force, large displacement, low rate actuation using both shape memory alloys (SMAs) and piezoceramics. Preliminary designs for a high force and high stroke SMA tendon actuator that will considerably exceed the force/stroke capabilities of any SMA actuator known to date have been completed.

(U) Program Plans:

- Littoral Force Architecture Study.
  - Explore connectivity relationships between elements of a Littoral Naval Force within this context.
  - Identify important scaling relationships for various platforms and systems.
  - Identify potential technology investments.
  - Develop a Concept of Operations for a Littoral Naval Force.
- Submarine Design Study.
  - Commence submarine concept design studies.
  - Conduct supporting displacement, cost engineering, technology and operational analyses.

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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                                     |  | <b>DATE</b><br>February 2004 |
| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development | <b>R-1 ITEM NOMENCLATURE</b><br>Marine Technology<br>PE 0603763E, Project, MRN-02, R-1 #45 |                              |

- Smart Actuator and Marine ProjectS demonstratiON (SAMPSON).
  - Demonstrate Smart Structures benefits by maximizing the integration of actuators with structures.
  - Develop smart materials based actuator performance.
  - Explore actuator performance.
  - Conduct SAMPSON performance testing and demonstration.
  - Model recent advances in low cost nanofluids shown to reduce friction.
  - Design, fabricate and test novel parasitic energy devices and associated supporting concepts/technologies.

|     |  |                       |                       |                      |
|-----|--|-----------------------|-----------------------|----------------------|
| (U) | <b><u>Program Change Summary:</u></b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|     | Previous President's Budget                                | 32.224                | 13.898                | 0.000                |
|     | Current Budget   | 26.164                | 13.751                | 0.000                |
|     | Total Adjustments  | -6.060                | -0.147                | 0.000                |
|     | Congressional program reductions                           | 0.000                 | -0.147                |                      |
|     | Congressional increases                                    | 0.000                 | 0.000                 |                      |
|     | Reprogrammings   | -3.250                | 0.000                 |                      |
|     | SBIR/STTR transfer   | -2.810                | 0.000                 |                      |

- (U) **Change Summary Explanation:**
- FY 2003     Decrease reflects SBIR transfer and minor repricing.
- FY 2004     Decrease reflects congressional undistributed reductions.

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

- Not Applicable

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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |         |        | R-1 ITEM NOMENCLATURE<br>Land Warfare Technology<br>PE 0603764E, R-1 #46 |         |         |                       |         |
| COST (In Millions)  | FY 2003 | FY2004 | FY2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost   | 164.634 | 81.513 | 63.121   | 102.700 | 55.000  | 15.000                | 15.000  |
| Rapid Strike Force Technology<br>LNW-01   | 10.327  | 0.819  | 0.721  | 0.000   | 0.000   | 0.000                 | 0.000   |
| Small Unit Operations LNW-02  | 30.808  | 17.704 | 0.000  | 0.000   | 0.000   | 0.000                 | 0.000   |
| Future Combat Systems LNW-03  | 123.499 | 62.990 | 62.400   | 102.700 | 55.000  | 15.000                | 15.000  |

**(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. Three broad efforts are being pursued in support of this objective: Rapid Strike Force Technology, Small Unit Operations and Future Combat Systems.

(U) The emerging U.S. vision of future land warfare places strong emphasis on technology supporting early entry of light, efficient land forces. 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: the Reconnaissance, Surveillance and Targeting Vehicle (RST-V); Tactical Mobile Robotics (TMR); Metal Storm (MS), Mach 5/50 Technology Development, and the Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration program. These programs are closely coordinated with the U.S. Army, Navy and Marine Corps, and with DARPA's Small Unit Operations (LNW-02) project.

(U) The Services are pursuing new tactical concepts for employing small, easily deployed units as an early entry force to address future contingencies. Their objective is to enable these forces to quickly control a large battlespace with dispersed forces, control the operational tempo, engage enemy targets with remote fire and operate effectively across the spectrum of conflict in severe communications environments. These dismantled forces must be self-sufficient, capable of operating for several days and be sufficiently lean to be quickly inserted anywhere in the world.

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(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.

| <b>(U) <u>Program Change Summary:</u></b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|--|-----------------------|-----------------------|----------------------|
| Previous President's Budget                                    | 165.963               | 82.387                | 15.433               |
| Current President's Budget                                     | 164.634               | 81.513                | 63.121               |
| Total Adjustments  | -1.329                | -0.874                | 47.688               |
| <br>   |                       |                       |                      |
| Congressional program reductions                               | 0.000                 | -0.847                |                      |
| Congressional increases  | 0.000                 | 0.000                 |                      |
| Reprogrammings   | 1.000                 | 0.000                 |                      |
| SBIR/STTR transfer   | -2.329                | 0.000                 |                      |

**(U) Change Summary Explanation:**

|         |   |
|---------|---|
| FY 2003 | Decrease reflects SBIR transfer and minor repricing.  |
| FY 2004 | Decrease reflects congressional undistributed reductions.   |
| FY 2005 | Increase reflects additional funds in Project LNW-03 for follow-on technology development for Block 2 and future Future Combat System configurations. |

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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |         |         | R-1 ITEM NOMENCLATURE<br>Land Warfare Technology<br>PE 0603764E, Project LNW-01 |         |         |                       |         |
| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Rapid Strike Force Technology,<br>LNW-01  | 10.327  | 0.819   | 0.721   | 0.000   | 0.000   | 0.000                 | 0.000   |

(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. 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: the Reconnaissance, Surveillance and Targeting Vehicle (RST-V); Tactical Mobile Robotics (TMR), Mach 5/50 Technology Development, and the Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration program. These programs are closely coordinated with the U.S. Army, Navy and Marine Corps, and with DARPA's Small Unit Operations (LNW-02) project. This project draws to an end in FY 2005. Programs traditionally budgeted in this project will be reflected in a new PE 0603766E, Project NET-01, to better reflect today's emphasis on network centric warfare.

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

|  |         |         |         |
|--|---------|---------|---------|
|  | FY 2003 | FY 2004 | FY 2005 |
| Reconnaissance, Surveillance and Targeting Vehicle (RST-V) | 4.142   | 0.000   | 0.000   |

(U) The Reconnaissance, Surveillance and Targeting Vehicle (RST-V) program is designing, developing, testing/demonstrating and transitioning to the Services four hybrid electric drive, lightweight, highly maneuverable advanced technology demonstrator vehicles capable of V-22 internal transport. The vehicle incorporates 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. Hardware and lessons learned from this program directly support the Marine Corps-Navy Extending the Littoral Battlespace (ELB) Advanced Concept Technology Demonstration



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| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development | <b>R-1 ITEM NOMENCLATURE</b><br>Land Warfare Technology<br>PE 0603764E, Project LNW-01 |                              |

(ACTD) as well as address joint U.S. Marine Corps – Special Operations Command (USMC-SOCOM) requirements for the Internally Transportable Vehicle/Light Strike Vehicle (ITV/LSV), Tactical Vehicle, Reconnaissance, Surveillance, Targeting and Acquisition (TV-RSTA) program and High Mobility Multi-purpose Wheeled Vehicle (HMMWV) upgrades. The Marine Corps will develop vehicle concepts and chassis, integrate the DARPA developed components and conduct vehicle performance tests (PE 0603640M) through participation in scheduled Advanced Warfighting Experiments (AWEs) and ACTDs (e.g., Capable Warrior).

(U) Program Plans:

- Completed Technical Performance Measure Verification.
- Completed safety testing at Aberdeen Proving Ground, MD.
- Performed user's demonstrations at Marine Corps Base Quantico, VA and McDill Air Force Base, FL.
- Conducted users' evaluation and assessment with potential USSOCOM/USMC customers at Yuma Proving Ground.
- Perform preliminary mobile power generator design.
- Refurbish and upgrade vehicle 1.
- Deliver vehicles 1, 2, 3 and 4.
- Deliver final report.

|                                | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------|---------|---------|---------|
| Tactical Mobile Robotics (TMR) | 0.100   | 0.000   | 0.000   |

(U) The Tactical Mobile Robotics (TMR) program developed mobile robotic technologies to enable land forces to dominate the battlespace through employment of mobile semi-autonomous robot teams performing challenging missions in complex environments (dynamic urban areas, rugged terrain with high obstacle clutter, etc.). TMR has provided DoD organizations with a team of semi-intelligent, cooperating robot prototype platforms carrying a variety of integrated mission payloads required to conduct activities in risk intensive or inaccessible areas. Operational emphasis was on urban environments and denied areas. TMR prototypes and research artifacts have been transitioned to the DoD Joint Robotic Program where they are being utilized to support additional research on robots.

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- (U) Program Accomplishments:
- Completed final prototype modifications.
  - Transitioned to military departments.

|                                  | FY 2003 | FY 2004 | FY 2005 |
|----------------------------------|---------|---------|---------|
| Mach 5/50 Technology Development | 1.189   | 0.819   | 0.721   |

(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 millimeter or larger bore) 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/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.

- (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 firing demonstration and deliver final report.
  - Transition hardware and data packages to DoD laboratories for Service-specific engineering and platform integration.

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|  | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration (ACTD) | 4.896   | 0.000   | 0.000   |

(U) The primary goal of the MAV 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 MAVs to accomplish unique military missions, particularly with regard to flight operations 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. It will be employable in a variety of warfighting environments, such as mountainous terrain and heavily forested areas. 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 will develop and deliver small, vertical lift, UAVs to military users for evaluation of the technology and for development of tactics, techniques and procedures. This program is funded in PE 0603764E, Project LNW-03 in FY 2004 and FY 2005.

(U) Program Plans:

- Demonstrate transition MAV (gasoline engine) in military operations in urban terrain exercises and conduct experiments with troops in field trials.
- Evaluate lessons learned and design of transition MAV.
- Develop and demonstrate diesel engine MAV.
- Conduct final experimentation of optimum diesel MAV; transition air vehicles and ground control system to USARPAC and complete final military evaluation.

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

| Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration (ACTD) | FY 2003 | FY 2004 | FY 2005 |
|--|---------|---------|---------|
| PE 0603750D, OSD   | 3.500   | 3.000   | 2.000   |

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005 | FY 2006   | FY 2007 | FY 2008               | FY 2009 |
| Small Unit Operations LNW-02  | 30.808  | 17.704  | 0.000   | 0.000   | 0.000   | 0.000                 | 0.000   |

(U) **Mission Description:**

(U) The Services are pursuing new tactical concepts for employing small, easily deployed units as an early entry force to address future contingencies. Their objective is to enable these forces to quickly control a large battlespace with dispersed forces, control the operational tempo, engage enemy targets with remote fire and operate effectively across the spectrum of conflict in severe communications environments. These dismounted forces must be self-sufficient, capable of operating for several days and be sufficiently lean to be quickly inserted anywhere in the world.

(U) The objective of the Small Unit Operations Project is to develop critical technologies that will enable small dismounted forces to effectively fight anywhere, anytime. The technology needs are: semi-automated maneuver and strike/fire planning and re-planning that can be employed by commanders who are physically separated but need to be virtually collocated; automated aggregation and mining of information sources to provide a “bubble” of awareness over each warrior and team describing the relevant situation; accurate geographic position estimation, other than GPS, which works in all environments; and radio links and self-forming ad hoc networked communications that “glue” the components together, operate in any environment, are covert and resistant to interference. In addition, these technologies must not significantly increase the dismounted force’s mass and power burden. The programs that make up this project include WolfPack, Tactical Sensors, and Advanced Sensing Technologies. This project draws to an end in FY 2005 and programs traditionally budgeted in this project will instead be located in Program Element 0603766E, Project NET-01, to better reflect today’s emphasis on network centric warfare.

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

|          | FY 2003 | FY 2004 | FY 2005 |
|----------|---------|---------|---------|
| WolfPack | 25.803  | 15.223  | 0.000   |

(U) The WolfPack program will develop technologies that would enable the U.S. to deny the enemy use of communications and radars throughout the battlespace. The networked system will be comprised of autonomous, ground-based monitors/jammers that are cooperatively linked to avoid disruption of friendly military and protected commercial radio communications and radars. The specific technologies to be developed include: (1) high efficiency sub-resonant antennas, (2) networking algorithms to allow coordinated access to the spectrum by communicators, jammers and signals intelligence (SIGINT) systems, (3) methods to easily deploy the systems in radio frequency (RF) advantaged sites, and (4) algorithms to rapidly and autonomously detect, classify, identify and jam target signals with low power electronics.

(U) In FY 2003, additional funding was added from the Defense Emergency Response Fund for an accelerated WolfPack capability. Early development of technologies that could lead to a rudimentary, near-real-time geolocation of our enemy's radio communications and surgical denial of those communication systems through the use of a precise coordinated response WolfPack-like system were analyzed. DARPA is developing long-term plans with the U.S. Army for deployment via airborne and deep-launch devices, and is working with the Air Force in a distributed suppression of enemy air defense role. Initial discussions with the Navy are taking place for littoral and force protection missions.

(U) **Program Plans:**

- Develop enabling technologies.
- Complete system design and performance analysis for a representative prototype system.
- Verify low duty cycle, low power jamming techniques with benchtop experiments.
- Construct and lab test brassboard-jamming subsystems.
- Conduct limited lab tests using brassboard equipment to attack several legacy type communication systems.
- Design, develop, and demonstrate via simulation and field tests the specific technologies developed.
- Studied enabling technologies for potential development of rudimentary WolfPack-capable system.

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|                  | FY 2003 | FY 2004 | FY 2005 |
|------------------|---------|---------|---------|
| Tactical Sensors | 1.750   | 0.000   | 0.000   |

(U) The Tactical Sensors program developed a new generation of unattended ground sensors, planning tools, deployment mechanisms, and command and control components that are providing Warfighters with the capability to continuously, remotely and cost effectively detect, track, classify and identify mobile tactical targets in all weather and all terrain. This lightweight, long-life system provides Warfighters with unmanned, high confidence reconnaissance, targeting, and surveillance, for integrated force protection and non-line of sight remote sensing in denied or life-threatening areas of interest.

- (U) Program Accomplishments:
- Completed development and field-tested unattended sensor and gateway nodes for detection, classification and tracking of mobile tactical targets such as mobile/cruise missile launchers, tanks, armored personnel carriers, logistics vehicles, light commercial vehicles, and personnel.
  - Developed planning and monitoring tools for Warfighters, including emplacement decision aids (EDA) using 3D topography, foliage, weather, traffic ability and target information. Provided for early Warfighter input, test, evaluation and redesign.
  - Integrated and demonstrated a fielded, deep-deployment system, followed by node self-erection and autonomous cluster organization, reporting and geo-location.
  - Interfaced to operational command and control networks, such as GCCS-M, GCCS-I, C2PC, or ASAS.
  - Demonstrated 70 percent probability of detection at 3,000 meters, 20 meters RMS tracking error at 500 meters, and greater than 90 percent probability of correct target identification at 500 meters, against heavy tactical vehicles operating under reasonably demanding environmental conditions.
  - Demonstrated 90 percent probability of detection and correct target classification at 30 meters for personnel; and greater than 85 percent probability of correct identification at 250 meters against light commercial vehicles operating under reasonably demanding environmental conditions.



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|                               | FY 2003 | FY 2004 | FY 2005 |
|-------------------------------|---------|---------|---------|
| Advanced Sensing Technologies | 3.255   | 2.481   | 0.000   |

(U) The Advanced Sensing Technologies program will develop a new class of sensors for military surveillance and targeting applications. These sensors will provide surveillance, target detection, tracking, and classification, in day or night and in near all-weather conditions, of time critical mobile targets at distances greater than ten times current capabilities. Such capabilities are required to maintain battlespace dominance in challenging environments where sensor shadow zones may exist, such as around man-made and natural terrain obstacles, under forest canopies and within dense foliage.

(U) Program Plans:

- Develop enabling technologies.
- Develop and field test stationary sensor system to detect, localize and characterize targets.
- Complete preliminary assessment of mobile sensor system to detect, localize and characterize targets in challenging environments.

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

- Not Applicable.

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005 | FY 2006   | FY 2007 | FY 2008               | FY 2009 |
| Future Combat Systems LNW-03  | 123.499 | 62.990  | 62.400  | 102.700   | 55.000  | 15.000                | 15.000  |

(U) **Mission Description:**

(U) The United States requires strategically deployable, operationally agile, highly lethal and survivable land forces capable of executing the full spectrum of military operations in a joint and multinational environment. This capability must provide our national leaders with increased options to respond to a growing array of crises and conflicts. To satisfy this requirement, the joint Army/DARPA Future Combat Systems (FCS) program was developed to provide dramatic enhancements to current and future land force lethality, protection, mobility, deployability, sustainability, and command & control capabilities.

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

|                         |         |         |         |
|-------------------------|---------|---------|---------|
|                         | FY 2003 | FY 2004 | FY 2005 |
| FCS Concept Development | 48.000  | 0.000   | 0.000   |

(U) The FCS program will develop network centric concepts for a multi-mission combat system that will be overwhelmingly lethal, strategically deployable, self-sustaining and highly survivable through the use of networked manned and unmanned ground and air platforms, sensors, and weapon systems. The goal of the FCS program is to design such an ensemble that strikes an optimum balance between critical performance factors, including ground platform strategic, operational and tactical mobility; lethality; survivability; and sustainability. The program will develop and demonstrate key enabling technologies, systems, and concepts for transition to a Major Defense Acquisition Program managed by the Army. This system of systems design will be accomplished by using modeling, simulation and experimentation. The FCS unit will be capable of adjusting to a changing set of missions, ranging from warfighting to peacekeeping, as the deployment unfolds. An FCS-equipped force will be capable of providing mobile-networked command, control, communication and computer (C<sup>4</sup>) functionalities; autonomous robotic systems; precision direct and indirect fires; airborne and ground organic sensor platforms; and adverse-weather reconnaissance, surveillance, targeting and acquisition.

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(U) The FCS program completed Concept and Technology Demonstration, achieved a Milestone B decision in May 2003, and transitioned to the System Development and Demonstration (SDD) phase. A systems integrator has been competitively selected by the FCS program. A group of 31 critical capabilities, with more than 100 candidate technology programs, were identified as integral to the baseline FCS configuration. For spiral development and incremental improvement to the FCS baseline, the Program Management Office (PMO) for FCS Technologies has identified multiple spiral insertion windows, and has begun plans for delivering Increment II capabilities. As part of the spirals, the program will insert 6 deferred systems, supported by more than 15 possible feeder technology programs, and will manage the potential insertion and integration of at least 12 identified technology insertion candidates. Additionally, the PMO will continue to research the technology base, including DARPA, Army, Joint Services, other DoD, industry, and international programs in order to meet future FCS requirements.

(U) The Future Combat Systems Lead System Integrator (FCS LSI), with direction from the Program Manager FCS-Technologies (PM FCS-TE), will develop the FCS Technology Development Strategy, the plan for the integration of enabling technologies and systems over the life of the FCS program. The LSI will coordinate the development of Transition and Integration Plans for the FCS Increment I deferred systems, and will coordinate and support the identification, maturation, and integration of technologies and systems into the FCS baseline. The LSI will coordinate or conduct System of Systems (SoS) and systems experiments to investigate technology and integration readiness. The LSI will assist Training and Doctrine Command (TRADOC) in developing operational concepts and requirements documents for Increment II. The LSI will also provide support to the Army Science Board and DARPA in assessing Technology and Concept Candidates for Increment II.

(U) Program Plans:

- Transitioned program from concept and technology development to system design and demonstration.
- Initiated Force Development Testing and Evaluation activities including limited man-in-the-loop testing.
- Initiated concept and technology demonstration (CTD) for follow-on block improvements.
- Developed a plan for identification and insertion of technologies deferred from baseline FCS platforms.

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|                             | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------|---------|---------|---------|
| FCS Supporting Technologies | 75.499  | 62.990  | 62.400  |

(U) DARPA and the Army identified key areas where technology development is needed to support the overall FCS system of systems design: robotic perception, unmanned ground combat vehicles, maneuver command control and communication (C<sup>3</sup>), beyond line of sight fires, organic adverse weather unmanned air vehicles and advanced radar and sensor systems.

(U) The Perception for Off-road Robotics (PerceptOR) program will identify and develop revolutionary unmanned vehicle perception prototypes. These perception systems will be flexible enough to operate in off-road environments and will be backed by extensive experimental test data in a variety of operationally relevant terrain and weather conditions. The resulting technology will be applicable to a variety of combat roles and will enable greater confidence in postulating the conditions under which unmanned off-road robotics should be used. The use of advanced remote imagery in aiding off-road navigation will be explored.

(U) The Unmanned Ground Combat Vehicle (UGV) program will develop vehicle prototypes exhibiting advanced performance in endurance, obstacle negotiation, and transportability (small size) based on novel designs unrestrained by the need to accommodate human crews. These prototypes may include unique mobility configurations (traditional wheeled to organic-mimicking, i.e. crawling), exceptional drivetrains, advanced structures/composites, terrain/soil analysis, sensory exploitation and interaction with robotic control architectures.

(U) The UGCV-PerceptOR Integration (UPI) program will exploit the expansion in UGV capability that merges inherent mobility, perception, and use of terrain data into one research platform that also allows for operational UGV considerations via real payload integration. Significant gains in mobility (obstacle negotiation and associated autonomous mobility), endurance, and payload fraction are expected by allowing the vehicle to operate without embedded crew comfort, protection, and fatigue factors. Smaller and lighter vehicles will be demonstrated, enabling a) reduced deployability burden for the associated combat payload, b) reduced combat service support associated with resupply, and c) reduced signature for gains in survivability.

(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. It incorporates both

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unmanned air and ground robotic platforms, higher headquarters working at the operational level, and human dismounts. MultiCell also provides commanders with recommended interface functions and workload allocations. MultiCell enables them to experimentally validate their understanding of the dynamics of their complex warfighting organizations. It defines commander interface layouts, functions and displays for maximum flexibility and effectiveness. It recommends capability enhancements in supporting technology for the nomination of sources of information. It supports visualization of current and future operational states. MultiCell enables commanders to successfully prosecute future command and control operations with significantly reduced staff.

(U) The Maneuver C<sup>3</sup> program will develop robust, assured and potentially high data rate connectivity for the Future Combat Systems (FCS) elements along with a command and control architecture to reduce the number of forward deployed Command and Control (C<sup>2</sup>) operators. The communications component will develop an integrated architecture that provides for a seamless transition from line-of-sight to non-line-of-sight communications. To enable this functionality, development of new secure waveforms, directional antennas and mobile ad hoc networks will be initiated. The C<sup>2</sup> component will directly leverage the Army's investment in the automation of the Battlefield Functional Areas within the Army Battle Command System (ABCS). Because of the multitude of single aspect systems that feed information in ABCS, large amounts of data are made available to the commander, thus requiring a much larger staff of operators and workstation analysts to complete the fusion function of battlefield data into information for the commander to make decisions. Future operations involving FCS technologies and operational capabilities cannot be restricted by a less responsive C<sup>2</sup> architecture and large support staffs.

(U) Under the Maneuver C<sup>3</sup> 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.

(U) The Integrated Multifunction Antennas (IMA) project will develop integrated multifunction affordable, low-profile/conformal antennas that achieve directionality via the antenna pattern and/or (distributed) arrays. These arrays will provide significant enhancement to signals intelligence (SIGINT), electronic warfare (EW), and JTRS communications functions in low band frequencies. Research will also be undertaken in this effort that will allow active protection, search, fire control radars, combat identification, and communications in high band frequencies.

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These antennas will be designed for use by ground combat vehicles with the objective of low profile and conformability. Multifunction affordable, low-profile/conformal antennas at the JTRS and mm-wave bands will significantly increase the combat capability of ground mobile combat vehicles through increased survivability (low visual and electronic signature; active protection function) and networked operations.

(U) The FCS C<sup>2</sup> program integrates and compresses selected Battlefield Functional Areas in a scaled architecture to support the FCS Unit Cell operations. Through emulation of advanced information technologies and knowledge base engineering, this program develops advanced methods of command and control, integrating the previously stove-piped Battlefield Functional Areas into a single information environment (Commander's Support Environment, CSE) that supports the command and control of manned and unmanned systems. The technical approach is to regulate the flow of information presented to an FCS Commander by moving much of the information/data integration to a hardware/software environment thus allowing the Commander and Battle Managers to leverage existing operational opportunities by focusing on fewer unknowns, and clearly visualize current and future operational end states and dictate the tempo of operations within a variety of environments, while being supported by a significantly reduced staff. The true compression and integration of these functions will provide the FCS commander with information for rapid decision making vice numerous data streams requiring analysis by a large battle staff. The compression of these selected functions would enable a reduction of personnel in the Unit Cell C<sup>2</sup> element, and facilitate anticipatory planning and adaptive execution by the FCS Commander. A top level C<sup>2</sup> architecture (systems and operational) will be developed and validation of the architecture and assessment of performance (e.g., command latencies) will be achieved by conducting a series of four experiments within a simulated environment.

(U) The Netfires (formerly Advanced Fire Support System) program will develop and test a containerized, platform-independent multi-mission weapon concept as an enabling technology element for FCS. NetFires will provide rapid response and lethality in packages requiring significantly fewer personnel, decreased logistical support and lower life-cycle costs, while increasing survivability compared to current direct fire gun and missile artillery. NetFires will allow FCS to defeat all known threats, will be air deployable in C-130 (and smaller) aircraft, and will enhance the situation awareness and survivability of FCS by providing standoff target acquisition and extended-range, non-line-of-sight engagements. The program will develop and demonstrate a highly flexible modular, multimission precision missile and a loitering attack missile that can be remotely commanded. Both missile types will have a self-locating launcher and a command and control system compatible with FCS.

(U) The Organic Adverse Weather Air Vehicle program provides FCS direct and indirect weapons system targeting under all operating conditions at the small unit level. The approach is to develop adverse weather vehicles for operation at two tiers; an upper tier for wide area coverage and a lower tier that allows a close-up view for positive target identification. For the higher tier, the A160 Vertical Take Off and

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Landing Unmanned Air Vehicle program will develop a vehicle for carrying out airborne surveillance and targeting against ground targets. The A160 vehicle will further provide an airborne communications/data link relay between the various ground components and the command nodes and satellite communications. In addition, the A160 will deploy unmanned ground sensors, unmanned ground vehicles, and Micro Air Vehicles (MAVs) and provide a data link between them and the C<sup>2</sup> components. For the lower tier, the Organic Air Vehicle 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, improved sensor combinations, improved navigation and obstacle avoidance, low-burden multi-vehicle command and control, 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 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 organic air vehicle to be developed in FY 2005 will be no greater than 112 lbs.

(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 is on the development of MAVs to accomplish unique military missions, particularly with regard to flight operations 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; heavily forested 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, vertical lift 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 program was funded in FY03 under project LNW-01.

(U) The Jigsaw program develops advanced laser radar (LADAR) sensor systems and technologies. Jigsaw will enable warfighters to accomplish day/night target identification and verification in stressing environments. Stressing environments include targets hidden by foliage and camouflage, and targets in urban settings, such as alleyways. Jigsaw technologies will provide warfighters with reliable combat identification; the LADAR sensor will deliver a visual picture of the target scene.

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(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. It 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 km against dismounted troops moving in forested areas. It employs adaptive antenna processing and innovative radar waveforms to overcome radio frequency interference and electronic countermeasures in hostile electromagnetic environments. This program was funded in FY 2003 in PE 0603762E, project SGT-04.

(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 region of their battlespace, including areas inaccessible or obscured to larger airborne assets.

(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 low-cost hyper spectral seeker. Ducted fan propulsion will provide efficient thrust for long



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endurance. The low cost hyper spectral seeker requires no gyroscopic stabilization. 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 hyper spectral seeker operating in visible 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 either be refueled in air, or 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) 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.

(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.

(U) The Future Combat Systems Studies, Analysis and Experimentation Project enables the continued Joint analysis and integration of enabling future land warfare concepts and technologies into the U.S. Army Future Combat System program. It enables the rapid analysis of opportunistic concepts and technologies, and provides support for Joint Force effectiveness modeling of DARPA enabling technologies by the TRADOC “Future’s Center.” The project has three initial focus areas: Air Assault Expeditionary Forces (AAEF), USMA Systems Engineering, and Directed Studies.

(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 and the OSD developed Joint Warfighting Simulation (JWARS). 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.

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(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 SilentEyes small UAV demonstrator and Steel Rattler (hand emplaced) and Steel Eagle (F-15 air emplaced) projects.

(U) The WolfPack program will further develop the initial capability for close approach electronic warfare. WolfPack was previously budgeted in PE 0603764E Project LNW-01. 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.

(U) Program Plans:

- PerceptOR
  - Conduct perception system prototype development testing in both laboratory and field.
  - Conduct evaluation experiments on early perception system prototypes in variety of terrain and environmental conditions.
  - Conduct algorithm development for advanced perception behavior.
  - Continue algorithm and supporting technology developments for unmanned maneuver.
  - Update prototype algorithms and hardware based on supporting experimentation.
  - Explore system implications of degraded component performance (communications constraints, sensor and other faults).
- Unmanned Ground Combat Vehicle (UGCV).
  - Conduct UGCV surrogate tests.
  - Conduct testing of prototypes against mobility, endurance, and payload fraction metrics.
  - Conduct resilience testing on prototypes and make reliability measurements.
  - Update prototype hardware with late development technology and prepare for extreme testing conditions.
- UGCV – PerceptOR Integration (UPI).
  - Initiate redesign and construction of four Spinner vehicles.

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- Optimize the PerceptOR system for integration onto Spinner.
- Initiate the selection of weapon payload and integrator.
- Conduct initial testing of two Spinner-Perception platforms.
- Complete weapon payload integration onto two Spinner platforms.
- Conduct second test of two Spinner-Perception platforms to demonstrate autonomy.
- Conduct initial testing of two Spinner-Payload platforms to demonstrate operation within selected warfighting scenarios.
- Complete goal-based testing of four Spinner platforms.
  
- MultiCell and Dismounted Command and Control.
  - Develop prototype command and control interfaces for higher commanders, cell commanders and dismount commanders.
  - Conduct human-in-the-loop experiments with dismounts and higher headquarters, including joint feeds.
  - Develop supporting operational and systems architectural framework products.
  - Develop a supporting C4ISR simulation test-bed to assess the performance of the C2 prototype.
  
- Maneuver C<sup>3</sup>
  - Validate organic, self-contained approaches versus approaches that “reachback” to other systems for C<sup>2</sup>.
  - 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 C<sup>2</sup> experimental demonstrator.
  - Continue experiments of Unit Cell C<sup>2</sup> incorporating limited activities of the dismounted soldier.
  - Extend C<sup>2</sup> architecture to handle inter-unit cell operations, and operations between unit cell and next higher level.

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- 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.
- Integrated Multifunction Antennas (IMA).
  - Develop multi-band antennas integrated into the composite armor and vehicle shell.
  - Incorporate and exploit the electromagnetic properties of the vehicle hull structure.
  - Determine the most beneficial multi-element integration to assure full hemispherical coverage and selective beam placement with respect to the vehicle.
  - Field test of antennas integrated on a Stryker or FCS vehicle mockup.
- Netfires
  - Completed controlled test vehicle demonstrations and initiate guided test vehicle demonstrations.
  - Conducted critical design reviews.
  - Investigated coordination of multiple Netfires missiles.
  - Completed guided test vehicle demonstrations and program transition.
- Organic Adverse - Weather Targeting Vehicles.
  - Initiate competitive contracts for system preliminary design.
  - Obtain and present data for candidate sensors and combinations for evaluation by users and developers.

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- Evaluate emerging communications and command/control systems and select best option(s).
- Evaluate preliminary designs and downselect to best design(s).
- Develop ~ 110 lb (dry weight) flight vehicle and demonstrate robust flight stability.
- Ground test A160 anti-icing systems, sand/dust/salt protection systems, and precision flight systems.
  
- Micro Air Vehicle .
  - Demonstrate transition MAV (gasoline engine) in military operations in urban terrain exercises and conduct experiments with troops in field trials.
  
- Jigsaw: LADAR Sensing for Combat ID.
  - 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 (FCS Class III) Unmanned Air Vehicle .
  - Develop real-time on-board registration and processing capability.
  
- 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.
  - 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.

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- 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.
  
- Affordable Weapon System.
  - Select an existing airframe as basis for missile design.
  - Replace engine with ducted fan.
  - Select and modify existing seeker.
  - Develop avionics package to support long-endurance flight.
  - Design and install port to support air-to-air refueling.
  - Conduct inert flight tests.
  - Integrate warhead.
  - Conduct final flight tests and live demonstration.
  
- 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.
  - Test surrogate rotors.
  - Integrate airframe with automatic controls.
  - Conduct airframe thermal and vibration testing.

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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                                     |  | DATE<br>February 2004 |
| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development | <b>R-1 ITEM NOMENCLATURE</b><br>Land Warfare Technology<br>PE 0603764E, Project LNW-03 |                       |

- 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 MINDEF and the U.S.
  - Conduct interoperability wargaming.
  - Assess the feasibility of using or developing Singapore’s quantum dot technology research for “next generation” multispectral goggles, and if feasible, to explore possible collaboration to develop this application with the US army.
  - Conduct perception system prototype development testing in both laboratory and field.
  
- Sensor Dart
  - Develop initial design concept that addresses separate Sensor Dart versions for both a Unit of Employment deployment and a Unit of Action deployment.
  - Conduct detailed trade studies and systems analysis 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.
  - Develop and flight test prototype.

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- 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:**

|                | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY 2005</u></b> | <b><u>FY 2006</u></b> | <b><u>FY 2007</u></b> |
|----------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| PE 633005 Army | 162.000               | 114.000               | 111.000               | 40.000                | 40.000                |



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| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |         |        | R-1 ITEM NOMENCLATURE<br>Network-Centric Warfare Technology<br>PE 0603766E, R-1 #48 |         |         |                       |         |
| COST (In Millions)  | FY 2003 | FY2004 | FY2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost   | 0.000   | 91.226 | 125.124   | 141.257 | 199.796 | 221.335               | 252.073 |
| Joint Warfare Systems NET-01  | 0.000   | 25.648 | 35.090  | 43.800  | 85.833  | 84.570                | 86.438  |
| Maritime Systems NET-02   | 0.000   | 13.253 | 29.327  | 34.586  | 38.482  | 45.391                | 49.248  |
| Classified NET-CLS  | 0.000   | 52.325 | 60.707  | 62.871  | 75.481  | 91.374                | 116.387 |

**(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 system concepts for today's network centric warfare concept. 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. 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.

(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

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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 and those in PE 0603763E.

|     |  |                       |                       |                      |
|-----|--|-----------------------|-----------------------|----------------------|
| (U) | <b><u>Program Change Summary:</u></b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|     | Previous President's Budget                                | 0.000                 | 95.654                | 151.966              |
|     | Current President's Budget                                 | 0.000                 | 91.226                | 125.124              |
|     | Total Adjustments  | 0.000                 | -4.428                | -26.842              |
|     | <br>Congressional program reductions                       | <br>0.000             | <br>-4.428            |                      |
|     | Congressional increases                                    | 0.000                 | 0.000                 |                      |
|     | Reprogrammings   | 0.000                 | 0.000                 |                      |
|     | SBIR/STTR transfer   | 0.000                 | 0.000                 |                      |

(U) **Change Summary Explanation:**

|         |  |
|---------|--|
| FY 2004 | Decrease reflects congressional program reduction for effects based network targeting and undistributed reductions.  |
| FY 2005 | Decrease reflects rephrasing of Loki and Effects Based Network Targeting and transfer of the Micro Air Vehicle ACTD and the Future Combat Systems Multicell programs to PE 0603764E, Project LNW-03. |

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Joint Warfare Systems NET-01  | 0.000   | 25.648  | 35.090   | 43.800  | 85.833  | 84.570                | 86.438  |

(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 operations. It leverages current and emerging network, robotic and information technology. This provides next generation U.S. forces with greatly expanded capability, lethality, and rapid responsiveness. The critical constraints facing this project are: (1) U.S. opponents are using and adapting network technology to make their systems more flexible and robust and more difficult to neutralize; and (2) U.S. doctrine limits the use of firepower to lessen the impact of operations on noncombatants. Meeting these challenges places a heavy burden on joint war planning. We must acquire an understanding of opponent networks and develop creative options to target them. We must synchronize air and ground operations to apply force only where needed and with specific effects. Finally, we must still be able to operate against fleeting targets of opportunity. The operational benefit of the Joint Warfare Systems project is an enhanced ability to counter opponents' capabilities, not just their facilities and equipment. This project will support 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 operational/tactical level, by managing highly automated forces with tight coupling between air and ground platforms; and (3) the focused tactical level, by developing platforms that can acquire targets of opportunity cued by network-based analysis of likely enemy operations.

(U) Future Combat Systems Multicell and Dismounted Command and Control, and Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration (ACTD) programs have moved to PE 0603764E, Project LNW-03.

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

|                                 | FY 2003 | FY 2004 | FY 2005 |
|---------------------------------|---------|---------|---------|
| Effects Based Network Targeting | 0.000   | 3.939   | 6.877   |

(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, social). One 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. It then nominates 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. It provides commanders a means to anticipate and counter an opponent's workarounds. Finally, it 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.
- Develop tools to analyze networks, singly and in combination, to identify vulnerabilities and predict effects of candidate interdictions.
- Demonstrate selected tools on real-world cases, validating them against historical and natural situations.

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|                                   | FY 2003 | FY 2004 | FY 2005 |
|-----------------------------------|---------|---------|---------|
| Confirmatory Hunter Killer System | 0.000   | 7.997   | 9.213   |

(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 continuous surveillance against limited (one or two) specific target classes. The program employs on-board electro-optics/infrared or low cost radar (motion cue or imagery based detection) sensors. It demonstrates an on-weapon automatic target recognition capability to detect the presence of a valid target vehicle and confirm engagement with the human operator. It also is capable of providing image-based, long-duration suppression of non-emitting surface-to-air and surface-to-surface missiles. The program delivers persistent, on-station munitions that enable rapid weapon response to emerging targets. The program's unmanned mechanisms patrol lines of communication and other delimited regions to prevent breakout, escape and reinforcement. The program enables suppression of targets emerging from suspect underground facilities. It provides the capability to suppress pop-up electronic warfare threats, before they have the opportunity to emit.

(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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|                 | FY 2003 | FY 2004 | FY 2005 |
|-----------------|---------|---------|---------|
| Network Command | 0.000   | 13.712  | 15.000  |

(U) The Network Command program leverages recent advances in network computing to dramatically improve collaboration among physically separate command posts. It allows commanders, and their staffs, to share situation information; to develop coordinated battle plans; to generate and compare alternate courses of action; and to assess likely outcomes, all without conventional group briefings. It builds on the paradigm established by the Command Post of the Future program which showed how commanders, working with voice-over-IP and robust graphical collaboration software, can build and maintain a coherent understanding of a situation and operational plan without any face-to-face interactions.

- The Command Post of the Future (CPOF) program continues to supply technical improvements to the baseline system deployed with the First Armored Cavalry Division. In particular, it increases network efficiency, analyzes system workload and performance data to tune system control parameters, and modifies display formats to increase the utility of information depicted and shared among the Division and Brigade level command posts. This is a continuation and expansion of CPOF efforts previously budgeted in PE 0603760E, Project CCC-02.
- The Multiuser, Adaptive Command Environment (MACE) program is an outgrowth of the Command Post of the Future (CPOF) program to make collaborative tactical command more adaptive, cross-functional, and scalable. It implants monitors in the collaboration environment to observe data traffic, identify patterns, and proactively move information through the system to meet users' needs more rapidly. It allows users to be distinguished by their military function – intelligence, maneuver, fires, security, logistics – and tailors displays and communication modes to those functions. Finally, it scales the environment from the dozens of workstations to hundreds of workstations operating over a diverse set of tactical communication networks.
- The Network-Centric Situation Assessment program develops and deploys technologies to assess military situations at levels of interest above individual targets. It uses all-source data to reconstruct unit organizations, mission relationships, logistics connections, and communications connectivity. It analyzes data over time to infer movement, communication, and supply patterns. With this context, it analyzes capabilities and hypothesizes future courses of action. 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. For

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commanders, this enables effects-based targeting, rather than simple attrition strategies. It provides a context for discovering vulnerabilities in opposing forces. It also provides cues for intelligence, surveillance and reconnaissance planning, as it suggests areas of future enemy activity that may merit more 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 still at their home stations, or en route to operations. The program uses current situation data to (1) provide initial conditions for the simulations; and (2) to plan data to steer the dynamics of the simulations along the selected courses of action. It streams data from the simulations to display and visualization systems available to the prospective participants. This allows them 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. It enables commanders and staff to participate from their current location, rather than a training facility. It thereby reduces deployment needs while improving mission planning and effectiveness.

(U) Program Plans:

- Command Post of the Future
  - Instrument 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.
- 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 feeds.



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- Joint Mission Rehearsal
  - Enhance existing mission simulations to require fewer 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 but not available at mission time.
  - Exercise these technologies.

|                                      | FY 2003 | FY 2004 | FY 2005 |
|--------------------------------------|---------|---------|---------|
| Precision Urban Combat System (PUCS) | 0.000   | 0.000   | 4.000   |

(U) The Precision Urban Combat System (PUCS) program will develop and validate a suite of advanced lethal and non-lethal precision and area capabilities for use by joint dismounted forces in urban combat operations. This program will consider the overall requirements for detection of potential enemy targets, discrimination and identification of friendly versus enemy units, sorting of enemy from neutral personnel, improved lethal and non-lethal response options, and assessment of results; and will develop a system response to the problem. Example technologies include: precision munitions with greatly improved accuracies (centimeters), 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, deterring or incapacitating agents, precision demolitions, hands-free weapons, and robotic applications. These systems will be developed within the framework of both legacy forces and expected future forces. The result will be to move precision munitions accuracies from meters to centimeters thus allowing very small weapons to be effectively employed; and to provide dismounted soldiers with increased capability and flexibility. 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.

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

- Not Applicable.

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| COST (In Millions)  | FY 2003 | FY 2004 | FY 2005  | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Maritime Systems NET-02   | 0.000   | 13.253  | 29.327   | 34.586  | 38.482  | 45.391                | 49.248  |

(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), which includes the Sea Sentry program, the Persistent Ocean Surveillance program, the Warfighting in the Littoral program, and Hologram. The MUDS concept represents the transformation of the LOKI concept (originally budgeted in PE 0603763E in FY 2003) into a more effective, distributed, networked capability.

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

|   |         |         |         |
|---|---------|---------|---------|
|   | FY 2003 | FY 2004 | FY 2005 |
| Mobile Undersea Distributed System (MUDS) Program (formerly Loki Program) | 0.000   | 13.253  | 25.927  |

(U) The Mobile Undersea Distributed System (MUDS) originated from the Loki Program in PE 0603763E, Project MRN-02. Preliminary results from the Loki program and its associated studies (including the Vortex Combustor testing) indicated that the program goals (enhancing operations in the littorals to counter asymmetric threat posed by diesel submarines and other forces operating in the littorals) would be best obtained by distributing efforts (development of a revolutionary "fighter-like" submersible and development of associated supporting systems) throughout a networked system. Therefore, the investment in the Loki program transitioned in FY 2003 into the Mobile Undersea Distributed Systems (MUDS) program. The network-centric MUDS program includes the Sea Sentry program, the Persistent Ocean Surveillance program, Warfighting in the Littoral program, Hologram, and Piranha.

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(U) The Sea Sentry 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 program will combine geolocation techniques such as the global positioning system with station keeping and intra-sensor communication technologies to provide long-term station keeping ocean environment sensing buoys. These technologies when applied with state-of-the-art undersea warfare sensors will result in a floating field of smart sensors capable of observing the undersea environment in an area, including the presence of submarines and other undersea vehicles. A range of technologies will be considered including those that rely on the local environment (such as wind, solar energy, temperature differentials, etc.) for their power, miniature geolocation technologies, and technologies for sensor data storage, transmission, and intra-field communications.

(U) The Warfighting in the Littoral program will explore potential technologies for successful operation in the littoral. It is the vehicle for investigating and developing technologies recommended by the joint DARPA/Navy Littoral Naval Force Architecture Study to explore future concepts and potential technologies for successful operation in areas defended by forces ashore, mines, submarines, small craft, and anti-ship missiles. Its principal focus is rapid access into contested littorals. 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.

(U) Hologram is an effort to demonstrate technologies necessary for a completely disruptive approach to littoral warfare. This is follow-on from previous efforts including Loki systems development and the Littoral Naval Force Architecture study. The program will include investigating and developing Micro-Autonomous Ocean Craft (MAOC) to spectrally emulate platforms comprising U.S. maritime expeditionary forces. The MAOC will operate in a networked/synchronized fashion, serving as a multi-dimensional counter measure for naval forces.

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Hologram will emphasize non-traditional approaches to naval warfare, focusing on emerging littoral operations and missions, and will focus on delivering capabilities vice platforms.

(U) The Piranha effort will enable submarines to engage elusive maneuvering land and sea targets by exploiting emerging battlefield Intelligence, Surveillance and Reconnaissance (ISR) sensors, wideband networked communications, real-time exploitation targeting algorithms, and existing/planned submarine strike weapon systems. This effort will develop key technologies that enable attack and cruise missile submarines to play a wider role in responding to time-urgent maneuvering targets from a forward-deployed position. The effort will focus on the following key technology areas that enable submarine strike missions in the littorals: continuous asymmetric connectivity to intelligence, sensors, weapons and other vessels while at depth; ISR sensor data exploitation for targeting (sensor-to-weapon handoff); advanced off board sensor concepts to include swarms of mini unmanned underwater vehicles (UUVs) for sensing sea targets; mobile underwater Global Positioning System (GPS) concepts; undersea networked sensor communications; and low latency target detection, identification, and geo-referencing. The effort will pursue a progression of more realistic demonstrations, culminating in closed-loop submarine engagement of moving ground surface vehicles and sea targets.

(U) Program Plans:

- Mobile Undersea Distributed Systems.
  - Continue investigation into novel communications and networking concepts.
- Sea Sentry.
  - Assess concepts employing swarms of undersea gliders 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 gliders.
  - Develop prototype low-cost, low-power, and glider based sensor/signal processing system, undersea sensor communications, and an underwater sensor localization and navigation capability.
  - Perform design trade studies, including: hydrodynamic performance modeling for advanced undersea glider concepts and advanced propulsion systems concepts.
  - Assess concepts for precise sensor localization and glider navigation systems.

|  |   |                       |
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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                                     |   | DATE<br>February 2004 |
| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development | <b>R-1 ITEM NOMENCLATURE</b><br>Network-Centric Warfare Technology<br>PE 0603766E, Project NET-02 |                       |

- Design and prototype a system of undersea autonomous gliders 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 oceanographic sized buoy using exploitable local environmental effects for 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.
- Hologram.
  - Develop technologies to enable access and sustain expeditionary forces.
  - Assess concepts for using the technology to deny enemy sanctuary, initiative and tactical opportunity.
  - Develop prototype sensor systems.
- Piranha.
  - Assess concepts for small area underwater mobile GPS systems.
  - Develop prototype low cost mini-UUV sensor systems, undersea sensor communications, and a mobile underwater GPS capability.
  - Design and prototype off-board Global Broadcast Satellite (GBS) antenna.
  - Demonstrate closed-loop submarine engagement of a moving ground surface vehicle by a submarine using off-board and traditionally non-available sensors.

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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                                     |  | <b>DATE</b><br>February 2004  |  |
| <b>APPROPRIATION/BUDGET ACTIVITY</b><br>RDT&E, Defense-wide<br>BA3 Advanced Technology Development |  | <b>R-1 ITEM NOMENCLATURE</b><br>Network-Centric Warfare Technology<br>PE 0603766E, Project NET-02 |  |

- Demonstrate endurance of underwater fiber optic link between global broadcast satellite antenna and moving platform.
- Receive operational ISR data over GBS at depth.
- Demonstrate Common Data Link (CDL) forward link to airborne receiver and receive tactical ISR data using CDL.

|                     | FY 2003 | FY 2004 | FY 2005 |
|---------------------|---------|---------|---------|
| Jet Blast Deflector | 0.000   | 0.000   | 3.400   |

(U) The Jet Blast Deflector 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.

(U) Program Plans:

- Demonstrate that multifunctional materials can reduce weight by 15-50% and will save operations and support costs by 26%.
- Test and validate performance and savings.

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

- Not Applicable.



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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                 |         |        |  |         |         | DATE<br>February 2004 |         |
| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA6 Management Support |         |        | R-1 ITEM NOMENCLATURE<br>Management Headquarters (Research and Development)<br>PE 0605898E, R-1 #132 |         |         |                       |         |
| COST (In Millions)   | FY 2003 | FY2004 | FY2005   | FY 2006 | FY 2007 | FY 2008               | FY 2009 |
| Total Program Element (PE) Cost  | 44.850  | 44.525 | 46.689   | 47.800  | 47.800  | 47.800                | 47.800  |
| Management Headquarters (R&D) MH-01  | 44.850  | 44.525 | 46.689   | 47.800  | 47.800  | 47.800                | 47.800  |

(U) **Mission Description:**

(U) This program element is budgeted in the Management Support Budget Activity because it provides funding for the administrative support costs of the Defense Advanced Research Projects Agency. The funds provide personnel compensation for civilians as well as costs for building rent, physical and information security, travel, supplies and equipment, communications, printing and reproduction.

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

|                         |         |         |         |
|-------------------------|---------|---------|---------|
|                         | FY 2003 | FY 2004 | FY 2005 |
| Management Headquarters | 44.850  | 44.525  | 46.689  |

(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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| <b>RDT&amp;E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)</b>                 |  | DATE<br>February 2004 |
| APPROPRIATION/BUDGET ACTIVITY<br>RDT&E, Defense-wide<br>BA6 Management Support | R-1 ITEM NOMENCLATURE<br>Management Headquarters (Research and Development)<br>PE 0605898E, R-1 #132 |                       |

|     |  |                       |                       |                      |
|-----|--|-----------------------|-----------------------|----------------------|
| (U) | <b><u>Program Change Summary:</u></b> <i>(In Millions)</i> | <b><u>FY 2003</u></b> | <b><u>FY 2004</u></b> | <b><u>FY2005</u></b> |
|     | Previous President's Budget                                | 42.271                | 45.002                | 46.489               |
|     | Current President's Budget                                 | 44.850                | 44.525                | 46.689               |
|     | Total Adjustments  | 2.579                 | -0.477                | 0.200                |
|     | <br>Congressional program reductions                       | <br>0.000             | <br>-0.477            |                      |
|     | Congressional increases                                    | 0.000                 | 0.000                 |                      |
|     | Reprogrammings   | 2.579                 | 0.000                 |                      |

- (U) **Change Summary Explanation:**
- FY 2003      Increase reflects a reprogramming for the pay raise increase to 4.1 percent.
  - FY 2004      Decrease reflects congressional undistributed reductions.
  - FY 2005      Increase reflects minor repricing.

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

- Not Applicable.