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February 2008

RESEARCH, DEVELOPMENT, TEST AND EVALUATION, DEFENSE-WIDE

Volume 1 - Defense Advanced Research Projects Agency

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DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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DEFENSE-WIDE
FY 2009 RDT&E PROGRAM

EXHIBIT R-1

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

Date: 17 JAN 2008

Line No	Program Element Number	Item	Act	Thousands of Dollars FY 2007	FY 2008	FY 2009	SEC
2	0601101E	Defense Research Sciences	01	139,521	174,996	195,657	U
	Basic Research			139,521	174,996	195,657	
11	0602303E	Information & Communications Technology	02	228,073	230,385	254,009	U
12	0602304E	Cognitive Computing Systems	02	165,395	174,680	145,262	U
13	0602383E	Biological Warfare Defense	02	99,926	72,101	66,291	U
16	0602702E	Tactical Technology	02	300,721	335,967	371,481	U
17	0602715E	Materials and Biological Technology	02	270,513	301,741	285,264	U
19	0602716E	Electronics Technology	02	215,742	196,707	211,457	U
	Applied Research			1,280,370	1,311,581	1,333,764	
31	0603286E	Advanced Aerospace Systems	03	58,414	71,925	107,857	U
32	0603287E	Space Programs and Technology	03	222,300	216,419	287,009	U
46	0603739E	Advanced Electronics Technologies	03	212,889	202,942	201,146	U
50	0603760E	Command, Control and Communications Systems	03	229,399	255,235	338,964	U
51	0603764E	Land Warfare Technology	03	36,658	19,642		U
52	0603765E	Classified DARPA Programs	03	147,159	186,992	196,697	U
53	0603766E	Network-Centric Warfare Technology	03	137,063	150,677	156,733	U
54	0603767E	Sensor Technology	03	189,795	195,213	226,470	U
55	0603768E	Guidance Technology	03	127,170	124,974	110,572	U
	Advanced Technology Development (ATD)			1,360,847	1,424,019	1,625,448	
137	0605502E	Small Business Innovative Research	06	78,657			U
146	0605897E	DARPA Agency Relocation	06			28,000	U
147	0605898E	Management HQ - R&D	06	48,766	48,480	52,700	U

DEFENSE-WIDE
FY 2009 RDT&E PROGRAM

EXHIBIT R-1

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

Date: 17 JAN 2008

Line No	Program Element Number	Item	Act	Thousands of Dollars FY 2007	FY 2008	FY 2009	SEC
153	0305103E	Cyber Security Initiative	06			50,000	U
		RDT&E Management Support		127,423	48,480	130,700	
		Total Research, Development, Test & Eval, DW		2,908,161	2,959,076	3,285,569	

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE: February 2008
APPROPRIATION/BUDGET ACTIVITY: RDT&E, Defense-wide; BA1 Basic Research	R-1 ITEM NOMENCLATURE: Defense Research Sciences; PE 0601101E

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	139.521	174.996	195.657	226.125	231.195	236.361	241.652
Bio/Info/Micro Sciences BLS-01	40.454	44.235	49.925	77.722	74.625	74.946	74.925
Information Sciences CCS-02	17.885	28.448	39.494	39.364	40.069	40.154	42.282
Electronic Sciences ES-01	50.091	53.481	57.505	61.360	58.898	62.752	62.752
Materials Sciences MS-01	31.091	48.832	48.733	47.679	57.603	58.509	61.693

(U) Mission Description:

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

(U) The Bio/Info/Micro Sciences project will explore and develop potential technological breakthroughs that exist at the intersection of biology, information technology and micro/physical systems to exploit advances and leverage fundamental discoveries for the development of new technologies, techniques and systems of interest to the DoD. Programs in this project will draw upon information and physical sciences to discover properties of biological systems that cross multiple biological architectures and functions, from the molecular and genetic level through cellular, tissue, organ, and whole organisms' levels.

(U) The Information Sciences project supports long term national security requirements through scientific research and experimentation in new computational models and mechanisms for reasoning and communication in complex, interconnected systems. The project is exploring novel means to exploit computer capabilities; enhance human-to-computer and computer-to-computer interaction technologies; advance innovative computer architectures; and discover new learning mechanisms and innovations in software composition. It is also fostering the computer science academic community to address the DoD's need for innovative computer and information science technologies.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E

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

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

(U) **Program Change Summary:** *(In Millions)*	**FY 2007**	**FY 2008**	**FY 2009**
Previous President's Budget	145.239	152.622	156.242
Current Budget	139.521	174.996	195.657
Total Adjustments	-5.718	22.374	39.415
Congressional program reductions	0.000	-1.119	
Congressional increases	0.000	23.493	
Reprogrammings	-2.000		
SBIR/STTR transfer	-3.718		

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E

(U) Change Summary Explanation:

FY 2007	Decrease reflects the reprogramming of the John H. Hopps congressional add to OSD and the SBIR/STTR transfer.
FY 2008	Increase reflects reductions for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions offset by congressional adds for Nanoscience Nanotechnology Institute, Illinois Institute of Technology, Nanocrystal Source Display, Bacterial Ghost Influenza Vaccine Development, Advanced Research to Further National Security Goals, Advanced Nano-Engineered Composites, Alternative Futures at the Range Complex Level for the Southwest U.S., Focus Center-GICUR University Research, and Advanced Photonic Composites Research.
FY 2009	Increase reflects the transfer of the Surface Enhanced Raman Scattering (SERS) program from PE 0602716E, Project ELT-01; Tip Based Nano Fabricate from PE 0603739E, Project MT-12; and increases to the University Photonic Centers, Quantum Entanglement Science and Technology Center, Computer Science Study Group and Young Faculty Awards.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Bio/Info/Micro Sciences BLS-01	40.454	44.235	49.925	77.722	74.625	74.946	74.925

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Bio Interfaces	8.000	7.960	11.000

(U) The Bio Interfaces program will support scientific study and experimentation, emphasizing the interfaces between biology and the physical and mathematical/computer sciences. This unique interaction will develop new mathematical and experimental tools for understanding biology in a way that will allow its application to a myriad of DoD problems. These tools will help exploit the advances in the complex modeling of physical phenomena such as Electro-Magnetic Pulse (EMP) and blast with biological tissues and cells in order to understand and prevent the deleterious effects of traumatic brain injury. It is also expected that understanding the fundamentals of biology will aid in developing tools to understand complex, non-linear networks and force structures.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

(U) Program Plans:

FY 2007 Accomplishments:

- Developed quantum mechanical theory of viral evolution incorporating horizontal gene transfer based on a path integral formalism – particle/wave duality in biology.
- Developed theory of speciation based on randomness in a fitness landscape and consequent Anderson localization.
- Completed initial evaluation of the mechanisms of explosive-induced traumatic brain injury in experimental models.
- Initiated observational study of clinical symptoms and biomarkers of traumatic brain injury in warfighter populations.

FY 2008 Plans:

- Strengthen the foundations of the metagenomics approach to ecology using population genetics and the analysis of evolving populations.
- Understand and exploit the consequences of the occurrence of quantum mechanical structure in biology.
- Develop new mathematical methods targeting complexity and variability in biological systems.
- Determine the primary physical factors accounting for explosive-induced traumatic brain injury in experimental models.
- Complete epidemiologic study of factors associated with explosive traumatic brain injury in warfighters.

FY 2009 Plans:

- Test and verify theoretical mathematical formulations of the laws of biology on simple systems.
- Complete development of a generalized thermodynamic formalism for biological systems.
- Create protection and mitigation strategies, which greatly reduce the number and extent of traumatic brain injuries in warfighter population due to explosion.

	FY 2007	FY 2008	FY 2009
Biological Adaptation, Assembly and Manufacturing	8.869	10.675	11.000

(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

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

required for the military (such as blood or other therapeutics). In addition, the fault tolerance present in biological systems will be exploited in order to assemble and manufacture complex physical and multi-functional systems, both biological and abiotic. Further activity in this area will investigate the adaptability of the brain to information processing and situational awareness. Applications to Defense systems include the development of chemical and biological sensors, and improved battlefield survivability of the warfighter.

(U) Program Plans:

FY 2007 Accomplishments:

- Genetically distinguished cells associated with regeneration from cells associated with a scarring response.
- Identified seven molecules that attract regeneration-associated cells.
- Identified novel human probiotic bacterial strains that reduce infectious diarrhea in experimental models.
- Demonstrated a novel bacterial ghost vaccine platform that increased survival after a lethal challenge of gut bacteria (Shigella).
- Identified novel human fibro-biotics that enable partial digestion of dietary fiber.

FY 2008 Plans:

- Decrease fibrotic collagen synthesis at a wound by 20% in an experimental model.
- Establish a population of blastema-like cells (defined by at least three genetic markers) at a non-regenerating wound site in a mammal.
- Develop strategies for production of ten red blood cell units per week for four weeks in an automated closed culture system using a non-renewing (replaceable) progenitor cell population.
- 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.
- Identify non-contact approaches such as magnetic fields and dielectrophoresis that provide cell positioning in 3-dimensions without negatively impacting cell viability.

FY 2009 Plans:

- Demonstrate production of 100 red blood cell units per week for eight weeks in an automated closed culture system using a renewing progenitor cell population.
- Enhance or produce artificial cell membranes to control, repair and improve cellular processes in the warfighter.
- Demonstrate in vitro construction of multicellular tissue using one or more non-contact cell positioning approaches.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

	FY 2007	FY 2008	FY 2009
Nanostructure in Biology	11.885	12.000	12.925

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

(U) Program Plans:

FY 2007 Accomplishments:

- Developed nanochannel glass recording devices to obtain neural impulses in the visual pathway; commenced test and verification.
- Designed and assembled multi-photon microscope to simultaneously record large number of neurons in order to understand the interconnectivity of neurons across regions in the mammalian visual pathway.
- From a priori mathematical principles, designed proteins that perform known chemistry in ten systems and showed that the naturally occurring protein appeared as one of the top five designs.
- Established methodology to design enzymes with high catalytic rate.
- Established methodology to mathematically design protein binding pairs.
- Demonstrated locomotion control using MEMS platforms consisting of ultrasonic projectors, pheromone ejectors, insect mechano-sensor activation, and visual presentation manipulation, neural, or muscular interfaces.

FY 2008 Plans:

- Create an in vivo map of the feature sensitivity of populations of primary visual cortical neurons using nanochannel glass reocordings and two-photon microscopy techniques.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

- Deduce how object representation in the mammalian inferotemporal cortex is computed from downstream visual system (V4) inputs using tools from topology, geometry, and statistics.
- Design enzymes with catalytic activity 10x improved from 2007 designs.
- Design proteins with 10x binding affinity to a second target protein.
- Demonstrate autonomous locomotion control via RF control for an un-tethered cyborg.

FY 2009 Plans:

- Create a functional model of the entire mammalian object recognition pathway that is biologically valid and suitable for translation to algorithm development.
- Apply protein design methodology to: 1) perform region-specific nitration chemistry, and 2) develop a protein that inhibits the activity of influenza by preferential binding.
- Develop a fast high-throughput chemistry-based technique for determining biomolecule structures at sub-Å resolution (better than X-ray crystallography) in solution.
- Optimize MEMS components for locomotion control, communications and power generation to consume less power and to reduce size, weight and cost.

	FY 2007	FY 2008	FY 2009
Human Assisted Neural Devices	10.500	12.000	15.000

(U) The Human Assisted Neural Devices program will develop the scientific foundation for understanding the language of the brain for application to a variety of emerging DoD challenges, including improving performance on the battlefield and returning active duty military to their units. This will require an understanding of neuroscience, significant computational efforts, and new material design and implementation. Key advances expected from this research include the ability to improve decision making in a variety of DoD applications including imagery analysis. In addition, this thrust will provide an understanding of how the brain adapts as it learns. This understanding will be translated into improved training approaches that allow transition from novices to expert in military tasks such as marksmanship to be accomplished with minimum effort and time.

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated neurally stimulated tactile feedback by a non-human primate in a reaching and grasping task.
- Developed new methods to discern motor intention in non-human primates.
- Determined the functional Magnetic Resonance Imaging (fMRI) signatures associated with expert status on DoD relevant tasks, which include skills that can make a direct translation to military benefit such as language acquisition, marksmanship, and threat detection.
- Commenced investigations into the neural basis of expert performance using advanced functional neuroimaging technologies, state of the art spatio-temporal measurement techniques and novel signal processing methods.

FY 2008 Plans:

- Create an interface capable of enabling performance of a complex motor/sensory task through an assistive device.
- Map dynamic functional motor and sensory networks, develop methods for characterizing brain-wide sensory/motor tasks, and determine task performance changes resulting from learning and plasticity.
- Identify the specific brain networks and regions involved in the generation of expert performance; track and classify progression from novice to expert level using functional neuroimaging techniques.
- Investigate non-invasive interventions to increase the speed of expertise development and dramatically accelerate the transition from novice to expert in key military tasks including neurophsyiologically-driven training regimens, neurally optimized stimuli, and stimulatory/modulatory interventions.

FY 2009 Plans:

- Develop prototype training systems to implement the acceleration methodologies for improved training.
- Explore the extrapolation of task specific acceleration techniques from limited domains to wider, more general training applications.
- Identify memory neural codes that are specific to critical work related tasks, enabling possible memory restoration in a brain-wounded warfighter.
- Leverage recent advances in neuroscience and mathematics to construct an integrated mathematical model of the brain that is consistent and predictive, rather than merely biologically inspired.
- Develop a theory that overcomes the difficulties present in traditional approaches, such as artificial intelligence and artificial neural network, to properly model complex human brain processes such as logical reasoning, language, mental computation, and context-dependent mental set.

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	FY 2007	FY 2008	FY 2009
Drug Discovery and Development Initiative for National Security	1.200	0.000	0.000

(U) Program Plans:
FY 2007 Accomplishments:
– Effort concentrated on finding promising new methods for discovering drugs to enhance national security efforts.

	FY 2007	FY 2008	FY 2009
Bacterial Ghost Influenza Vaccine Development	0.000	1.600	0.000

(U) Program Plans:
FY 2008 Plans:
– Develop novel genetically inactivated bacterial-based vaccines to overcome disadvantages of egg-based vaccines.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project CCS-02

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Information Sciences CCS-02	17.885	28.448	39.494	39.364	40.069	40.154	42.282

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Computer Exploitation and Human Collaboration	13.312	20.512	11.494

(U) The Computer Exploitation and Human Collaboration program supports research in broad areas of computational science having the potential for revolutionary advances in performance and other relevant metrics above and beyond extrapolations of current approaches. The research will yield significant advances in networking, software, hardware, and computational systems that will allow warfighters and commanders of the future to interact in a natural way with computers, enable a new generation of collaboration methods and information acquisition, and provide intelligent seamless exchange of information in a world where computing devices are ubiquitous and heterogeneous. The program is creating an information theory for ad-hoc mobile wireless networking in the absence of wired infrastructure; practical inferential reasoning techniques applicable in real-world situations with complexity and uncertainty; and revolutionary non-traditional processing architectures. The Computer Exploitation and Human Collaboration program consists of two efforts: Information Theory for Wireless Mobile Ad-Hoc Networks (ITMANET) and Real-World Reasoning (REAL).

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project CCS-02

- The science of interconnected systems provides powerful mathematical tools for understanding the intrinsic properties and complexities of large-scale networks and other distributed systems. Such foundational research is imperative for the future design of robust systems that break away from the established tradition of piece-meal patching of current infrastructures. Research is focused on the development of an overarching "Information Theory for Wireless Mobile Ad-Hoc Networks" (ITMANET). This revolutionary information theory effort will enable the next generation of the DoD's wireless networks, and moreover provide insight concerning the acquisition and deployment of nearer-term systems.

- Research on machine intelligence over the last two decades has revealed that many reasoning problems are inherently computationally complex, and in many cases, intractable. Solutions to these problems typically require either enormous computer resources, or simplification of the problem resulting in major sacrifices to accuracy. The Real-World Reasoning (REAL) effort is developing foundational technologies, heuristic approaches, and tools necessary to enable effective, practical machine reasoning about increasingly complex and large-scale problems. These technologies will aid commanders and warfighters in assessing the consequences of specific actions and strategies, and will help in predicting future results. The key technologies under investigation are effective, practical inferential reasoning in real-world situations with complexity and uncertainty; novel paradigms for learning while reasoning; integration of multiple reasoning paradigms; representation and reasoning with information that changes over time; reasoning about the goals of other agents; and appropriate metrics for measuring cognitive behavior and performance.

(U) Program Plans:

– Information Theory for Wireless Mobile Ad-Hoc Networks (ITMANET)
  FY 2007 Accomplishments:
  -- Initiated work by two university research teams to develop a revolutionary information theory for mobile ad-hoc networks (ITMANET) that will provide theoretical underpinnings and performance goals/limits for the next generation of DoD wireless networks as well as practical guidance for the acquisition and deployment of near-term systems.
  -- Analyzed single flow "line" network containing key forms of dynamics in terms of throughput/delay-reliability trades.
  -- Used stochastic geometry to model cooperation in power control and scheduling; explored and quantified the benefits of cooperation using this model.
  -- Analyzed, prototyped, and demonstrated novel forms of physical-layer radio cooperation based on analog network coding and information-theoretic relaying.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project CCS-02

FY 2008 Plans:
-- Develop and analyze tractable and insightful metrics and network models that expand the definition of information theory to encompass the degrees of freedom, constraints and dynamics inherent to wireless networks.
-- Develop new upper bounding techniques for MANET capacity and other performance metrics, and evaluate these bounds for small to medium-sized networks under relatively simple assumptions.
-- Develop new achievability results for key performance metrics by optimizing dynamic node cooperation and resource allocation over available degrees of freedom.
-- Use rate distortion theory and network utilization to optimize the interface between networks and applications.

FY 2009 Plans:
-- Predict MANET performance in terms of throughput-delay-reliability for a specific pre-defined MANET realization (small number of nodes, maximum limited mobility, required outage, amount of allowed overhead, bandwidth efficiency, etc.).
-- Develop new achievability results for key performance metrics based on networks designed as a single probabilistic mapping with dynamics over multiple timescales.

– Real-World Reasoning (REAL)

FY 2007 Accomplishments:
-- Demonstrated, on problems of limited scope, a new learning-based algorithm that achieves a 10^9 speed-up in logical Quantified Boolean Formulae (QBF) reasoning.
-- Demonstrated, on small problems, new reasoning algorithms that combine pruning, consistency models, and statistical sampling to decide on a course of action even when the state of the world is unknown.
-- Determined, on small problems, that Nash equilibrium points could be identified in multi-party, mixed tactical/strategic settings, determining which action a commander should take and with whom to partner in a given situation.
-- Provided program planning support for the DARPA Urban Challenge.

FY 2008 Plans:
-- Develop innovative algorithms for dramatically reducing the complexity and processing required for reaching conclusions in logical reasoning systems where the problems are of an operationally realistic scale and complexity.
-- Develop reasoning algorithms that can analyze situations and decide on effective courses of action even when the exact state of the world is unknown (a.k.a. partial observability) on problems of realistic size and complexity.

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-- Develop strategic reasoning algorithms that analyze complex, multi-party, mixed tactical / strategic settings (like those found in modern warfare situations), and provide decision support to warfighters about who is partnered with whom and what posture might be taken with respect to these parties; where the problems are of realistic size and complexity.

FY 2009 Plans:

-- Develop a system architecture that integrates the different REAL technologies into a cohesive reasoning system.
-- Apply the REAL system (combined technologies) to a military training simulation called Decisive Action.
-- Create non-traditional computing architectures that go beyond the currently deployed instruction set architectures and the long-standing abstraction layer paradigm of application on operating system on kernel on assembler on firmware on hardware.

	FY 2007	FY 2008	FY 2009
Computer Science Study Group (CSSG)	4.573	6.936	12.000

(U) The Computer Science Study Group (CSSG) program supports emerging ideas from the computer science academic community to address the DoD's need for innovative computer and information science technologies; introduce a generation of junior researchers to the needs and priorities of the DoD, and enable the transition of those ideas and applications by promoting joint university, industry, and government projects. The CSSG project formalizes and focuses this research for efficiency and greater effectiveness.

(U) Program Plans:

FY 2007 Accomplishments:

- Established comprehensive study panels comprised of junior academic computer scientists and paired them with mentors with senior academic, industrial, and military talents.
- Conducted a series of research efforts in order to solve the most compelling problems facing the computer science community.
- Initiated development of a sensitive programming language focusing on code behavior in problem environments.
- Initiated development of a secure, coherent software methodology for information-sharing for both cross-domain and intra-domain communication applications.
- Developed research paradigm to solve bottlenecks and inefficiencies in network data transfer, using the novel concept of image hand-printing for efficiently locating sources of similar content.

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FY 2008 Plans:
- Further develop extensive collaboration among civilian computer scientists and DoD technologists and customers.
- Develop software models of human skin architecture including sensory neural system.
- Develop new computational learning theory, including learning from noisy data, to enhance algorithms for random noise tolerance.
- Develop software with increased capability and dependability, by combining static tools and human insight at the architectural level to defeat attacks.
- Develop process for networking wireless imaging systems and other wireless sensors emphasizing change detection and medical applications.

FY 2009 Plans:
- Identify and explore new computer science challenges that, when addressed, will yield extraordinary advances for DoD applications.
- Develop high-performance parallel computing, and interactive computer graphics.
- Explore bio-inspired computing emphasizing evolutionary computation and artificial neural networks (ANNs) to solve difficult real world tasks such as autonomous guidance of vehicles.
- Develop new approaches for management of network security, authentication, mobility, and handoff management with emphasis on self-organizing wireless networks in a battlefield environment.

	FY 2007	FY 2008	FY 2009
Programmable Matter	0.000	0.000	4.000

(U) The Programmable Matter program will develop a new functional form of matter, constructed from mesoscale particles that assemble into complex 3-Dimensional (3-D) objects upon external command. These objects will exhibit all of the functionality of their conventional counterparts and ultimately have the ability to reverse back to the original components.

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(U) Program Plans:
FY 2009 Plans:
- Build mathematical model that theoretically confirms a viable procedure for constructing macroscopic 3-D solid objects with functional properties that have real world use.
- Demonstrate externally-directed assembly of distinct macroscopic 3-D solids.
- Demonstrate interlocking/adhesion of mesoscale particles to create bulk matter.
- Demonstrate reversibility.

	FY 2007	FY 2008	FY 2009
Young Faculty Award	0.000	0.000	10.000

(U) The Young Faculty Award (YFA) program will identify rising research stars in junior faculty positions in academia and expose them to DoD needs and DARPA's program development process. The long term goal is to develop the next generation of academic scientists in key disciplines who will focus a significant portion of their career on DoD and National Security issues.

(U) Program Plans:
FY 2009 Plans:
- Identify brightest young academicians in microsystems, mathematics, neuroscience and other disciplines as candidates for the program.
- Conduct introductory meetings to introduce academicians/faculty to DoD needs and opportunities.
- Develop broad areas of scientific interest; solicit, evaluate, and fund proposals.

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	FY 2007	FY 2008	FY 2009
High School Science Study Group/CS Futures	0.000	1.000	2.000

(U) The DARPA Grand & Urban Challenges inspired a number of high school-age students and exposed them to the rewards of a research career. The future of DoD research depends on the continuing engagement of these students in science- and technology-related fields. An offshoot of the Computer Science Study Group program, the High School Science Study Group/CS Futures program will fund efforts to identify the computer science interests of high school students, and involve them in high-level research at the high school level.

(U) Program Plans:

FY 2008 Plans:

- Assemble a panel of academic computer scientists to identify potential areas of interest to high school students.
- Establish student study groups to gauge the attractiveness of the proposed ideas to students.
- Conduct student evaluation of potential research to include: robotics for traffic and vehicle management, robots for environmental surveillance and conservation, and object recognition for the blind.

FY 2009 Plans:

- Engage high school study groups to work on selected ideas.
- Continue evaluation of new potential ideas, including: human computer interactions, computational models of environmental adaptation, and automated evaluation of physical function for applications in rehabilitation medicine.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Electronic Sciences ES-01	50.091	53.481	57.505	61.360	58.898	62.752	62.752

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
University Photonic Research (UPR) Centers	7.102	5.782	7.500

(U) The University Photonic Research (UPR) Centers 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

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engagement. Topics researched include emitters, detectors, modulators and switches operating from infrared to ultraviolet wavelengths, and related heterogeneous materials processing and device fabrication technologies for realizing compact, integrated optoelectronic modules.

(U) The University Photonics Research (UPR) II program will continue long standing support of university-led research in photonics. The program will develop revolutionary capabilities leading to specific photonic intelligent microsystems by using university-based teams of interdisciplinary researchers engaged in a range of topics. These university-based research projects will be coupled with industry participation. Unfunded participation of industry researchers is expected to help guide and focus the Centers' activities toward specific and measurable research goals. The industrial liaisons are expected to facilitate transitioning the intermediate results of long term research into products in addition to providing an industry perspective. The overall vision of the Centers' research programs will be driven by the goal of creating new paradigms for realizing higher performance, lower energy requirements, greater environmental stability and adaptive behavior. Each team of university researchers will be formed into a University Photonics Research Center, and will be associated with an overarching vision of research directions.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated detection of a single molecule in a fluidic bath using an optical micro-resonator with a functionalized surface to show simultaneous high selectivity and high sensitivity detection of unlabeled biological or chemical compounds.
- Demonstrated nano-aperture vertical cavity surface emitting lasers with record high intensity output showing that established theory for sub-wavelength optical apertures is incorrect.
- Initiated projects jointly funded by industrial sponsors.

FY 2008 Plans:

- 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.

FY 2009 Plans:

- Evaluate the performance characteristics of the prototype modules and determine the highest payoff dual use development paths.
- Identify and enlist industrial participants.
- Identify a common set of photonic devices most widely used/requested and make them immediately available for experimentation.

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	FY 2007	FY 2008	FY 2009
Semiconductor Technology Focus Centers	20.400	10.200	20.000

(U) The Semiconductor Technology Focus Centers research program is a collaborative effort between the Defense Advanced Research Projects Agency (DARPA), the Office of the Deputy Undersecretary of Defense for Science & Technology (DUSD/S&T), and the Microelectronics Advanced Research Corp (MARCO) which will establish new Focus Centers in "Materials, Structures & Devices" and in "Circuits, Systems & Software" at U.S. Institutions of Higher Education. The Focus Centers will concentrate research attention and resources on a discovery research process to provide radical innovation in semiconductor technology that will provide solutions to barrier problems in the path of sustaining the historical productivity growth and performance enhancement of semiconductor integrated circuits. The overall goal of this collaborative effort between the Department of Defense and industry is to sustain the unprecedented four decades of uninterrupted performance improvement in information processing power.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed efficient platform based design methodologies and low latency interconnect technologies for complex integrated circuits that have application in high performance signal processing and communication systems.
- Developed circuit architectures that reduce long interconnects compatible with chip clock rates > 5 gigahertz (GHz).
- Explored novel device fabrication and integration approaches for deeply scaled transistors (<10 nanometers channels) and their effective integration for high performance mixed signal circuits for military needs.
- Demonstrated capabilities of platform-centered design methodology leading to rapid design and re-design of complex System on a Chip (SoC) for military applications.
- Demonstrated photonic, radio frequency (RF), and novel materials for on-chip interconnects.
- Demonstrated fabrication technologies for nanometer scaled transistors.
- Developed robust designs and architectures for fabricating circuits based on unreliable switches.

FY 2008 Plans:

- Demonstrate, via simulation, integration of nanometer-scaled devices into circuit macro functions that have application to military sensor signal processing or advanced communications protocols.

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– Explore integration processes for incorporating high mobility materials as transistor channels in deeply scaled field-effect transistors.
– Explore new materials and fabrication approaches to scale devices below 10 nanometers (nm).

FY 2009 Plans:

– Develop novel device fabrication and integration approaches for deeply scaled transistors and architectures for high performance mixed signal circuits for military needs.
– Develop concepts and validation methods in one or combinations of the following areas: electronics, photonics, micro-electro-mechanical systems (MEMS), architectures and algorithms.

	FY 2007	FY 2008	FY 2009
Focus Center - Government Industry Cooperative University Research (GICUR)	0.000	8.000	0.000

(U) The Focus Center - Government Industry Cooperative University Research (GICUR) program compliments the goals and objectives of the above Semiconductor Technology Focus Centers. All plans are identical. All funding is applied to the Semiconductor Technology Focus Center program.

	FY 2007	FY 2008	FY 2009
Molecular Photonics (MORPH)*	8.060	5.000	0.000

*Formerly Supermolecular Photonics Engineering.

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

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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:

FY 2007 Accomplishments:

- Demonstrated a polymer-based signal modulator with far higher speed (20 gigahertz (GHz)) than semiconductor modulators of similar size while having comparable performance (impact on RF photonics).
- Demonstrated organic molecules with high optical limiting for sensor protection from laser threats (warfighter protection).

FY 2008 Plans:

- Demonstrate very high speed (100 gigahertz (GHz)) polymetric electro-optic (EO) modulator.
- Demonstrate organic materials for building ultra-high speed EO modulators.
- Develop tailored organic materials as high-efficiency optical limiters in regions of the spectrum relevant to military sensor protection.

	FY 2007	FY 2008	FY 2009
Photonics Technology Access Program (PTAP)	1.300	0.000	0.000

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

(U) Program Plans:

FY 2007 Accomplishments:

- Employed a broker-supplier user model that has been previously tried for integrated circuits and micro-electro-mechanical systems to implement the program.
- Evaluated the number of device/material transactions implemented between users and suppliers.

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	FY 2007	FY 2008	FY 2009
Quantum Entanglement Science and Technology (QuEST)	3.927	2.600	5.000

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

(U) Program Plans:

FY 2007 Accomplishments:

- Initiated research in fundamentals of quantum information science, quantum algorithms and applications of small (several qubit) quantum systems.

FY 2008 Plans:

- Continue exploration of fundamental quantum systems.

FY 2009 Plans:

- Develop novel approaches to improving decoherence times.
- Devise full characterization and manipulation of entangled quantum systems.
- Formulate novel quantum algorithms.

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	FY 2007	FY 2008	FY 2009
N/MEMS Science and Focus Centers	9.302	9.432	13.282

(U) The goal of the N/MEMS Science and Focus Centers program is to support the development of an enhanced fundamental understanding of a number of important technical issues critical to the continuing advance of nanoelectromechanical systems (NEMS) and microelectromechanical systems (MEMS) technologies and their transition into military systems. The basic research work to be conducted under the program is responsive to recognized challenges in a comprehensive range of technical areas pertinent to future DoD needs. Industrial cost sharing is an important element of the overall effort.

(U) Program Plans:

FY 2007 Accomplishments:

– Developed a fundamental understanding of the behavior of materials interfaces and associated reliability.

FY 2008 Plans:

– Fabricate non-lithographic MEMS.
– Develop an understanding of fluidics on a nanoscale.

FY 2009 Plans:

– Develop MEMS enabled reconfigurable electronics.
– Develop ultra-high Q (energy ratio) nanoresonators.

	FY 2007	FY 2008	FY 2009
Semiconductor A1GaN Injection Lasers (SAIL)	0.000	1.049	3.168

(U) The objective of the Semiconductor AlGaN Injection Lasers (SAIL) program is to demonstrate lasers with ultraviolet emission in the wavelength range of 340 to 270 nanometers (nm). These lasers will be based on heterostructures of Aluminum Gallium Nitride (AlGaN). Such lasers do not exist at present. Once demonstrated, SAIL devices are expected to have applications in stand-off bio-defense, such as point detection of aerosolized bio-agents.

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(U) Program Plans:

FY 2008 Plans:

- Develop methods for preparing AlGaN with low density of dislocations.
- Demonstrate effective p-type doping in AlGaN with the aluminum nitride (AlN) content of 60%.

FY 2009 Plans:

- Fabricate injection lasers operating in the ultraviolet at 340 nm and 280 nm.
- Demonstrate stable and reliable operation of ultraviolet lasers at room temperature.

	FY 2007	FY 2008	FY 2009
Nanoscaled Architecture for Coherent Hyper-Optic Sources (NACHOS)	0.000	3.525	3.555

(U) The Nanoscaled Architecture for Coherent Hyper-Optic Sources (NACHOS) program will explore scaling rules for semiconductor laser sources. Such rules exist and are well understood in electronics but do not yet exist for photonic devices. Nanoscaled lasers would be useful in a wide range of applications, from close integration with electronics, on chip light sources, to single photon sources. The program idea is based on recent developments in heterostructured semiconductor nanowires (the gain medium), which establish the feasibility of forming lasers with diameters much smaller than the wavelength of light they produce. Simultaneously, advances in plasmonic structures, which support optical frequencies with X-ray like wavelength, make it possible to envision feedback structures (cavities) that are also shorter than the wavelength of light emitted from the cavity. The program goal will thus be to produce nanoscaled lasers with all three dimensions shorter than the wavelength of light. Important issues of beam shaping through antenna-like structures and powering via plasmonic structures will also be considered.

(U) Program Plans:

FY 2008 Plans:

- Develop defect-free nanowire-based heterostructures.
- Grow lithographically defined nanowire heterostructures.
- Use photonic bandgap structures for feedback and coupling of light.

FY 2009 Plans:

- Establish and validate models for nanophotonics.

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	FY 2007	FY 2008	FY 2009
Tip-Based Nanofabrication (TBN)	0.000	0.000	5.000

(U) The Tip-Based Nanofabrication (TBN) program will develop methods for precise, repeatable, manufacturing at the nanoscale, using Atomic Force Microscope (AFM) tips as tools. Confinement of extreme conditions (temperatures, fluxes, fields & forces) to the region within a few microns of the tip will enable heterogeneous integration of normally incompatible materials.

(U) Programs Plans:
FY 2009 Plans:
- Develop a new nanomanufacturing technology based on extreme fields and fluxes available in the region of a nanoprobe tip.
- Build unique nanometer-scale device structures.
- Demonstrate post-complementary metal-oxide-semiconductor (CMOS) local nanofabrication.

	FY 2007	FY 2008	FY 2009
Illinois Institute of Technology	0.000	1.040	0.000

(U) The Illinois Institute of Technology program will explore new approaches to advanced electronics technology.

(U) Program Plans:
FY2008 Plans:
- Initiate development of advanced electronics technologies.

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	FY 2007	FY 2008	FY 2009
Nanocrystal Source Display	0.000	1.200	0.000

(U) The objective of Nanocrystal Source Display program is to develop nanoscale crystals for display applications.

(U) Program Plans:
FY2008 Plans:
- Initiate nanocrystal development.

	FY 2007	FY 2008	FY 2009
Advanced Photonic Composites Research	0.000	3.253	0.000

(U) The objective of Advanced Photonic Composites Research is to develop advanced optical composites for defense applications.

(U) Program Plans:
FY 2008 Plans:
- Transition nano-engineered materials and composites into DoD relevant devices with a specific focus on advancing infrared detectors and energy harvesting structures.
- Develop and commercialize composite technology in integrated optics.

	FY 2007	FY 2008	FY 2009
Nanoscience Nanotechnology Institute	0.000	2.400	0.000

(U) The Nanoscience Nanotechnology Institute will explore new approaches to nanoscience research.

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(U) Program Plans:
FY 2008 Plans:
– Initiate nanoscience research.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Materials Sciences MS-01	31.091	48.832	48.733	47.679	57.603	58.509	61.693

(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 2007	FY 2008	FY 2009
Nanoscale/Biomolecular and MetaMaterials	12.029	16.500	17.500

(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 material properties. This includes efforts to develop the underlying physics for the behavior of materials whose properties have been engineered at the nanoscale (Metamaterials).

(U) Program Plans:

FY 2007 Accomplishments:

- Developed a cluster expansion method for material properties that achieved 10^6 reduction in the number of calculations.
- Developed an instantiation for quantum monte carlo calculations linear in the number of particles.
- Developed a new method for predicting material properties based upon linear combinations of atomic potentials.
- Demonstrated a laser driven, 1 billion electron volt electron beam.
- Designed composite nano-material structures and demonstrated processing capabilities for achieving improved optical and mechanical properties over existing infrared windows.
- Developed and applied new theory for multiple input multiple array radar systems that lead to 10x improvement in missed target detection while providing 10x reduction in search volume.

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– Demonstrated a new digital coding scheme to simultaneously exploit spatial, temporal, and polarization diversity that led to a 15x improvement in signal/clutter ratio in the Naval Research Laboratory Advanced Multi Function Radar System.

FY 2008 Plans:

– Predict and synthesize new thermoelectric materials with a figure of merit ZT > 5.
– Develop efficient computational methods that correctly predict the properties of excited electronic states.
– Demonstrate laser-initiated production of ultra violet (UV) light via harmonic generation.
– Achieve mid-wave infrared optical transmission comparable to that of spinel with mechanical properties comparable to those of sapphire.
– Demonstrate infrared optical transmission in 75mm disks.

FY 2009 Plans:

– Develop methods to connect theoretical materials to experimental methods to support verification of the predicted properties of the theory.
– Demonstrate interleaved production of electron beam and X-ray or UV light from laser-initiated processes.
– Demonstrate hemispherical and aerodynamic domes with decreased optical scatter, doubled mechanical strength, and doubled thermal shock capabilities over single crystal sapphire.
– Develop the capability to inexpensively mass manufacture large quantities of customized diatom-derived structures and materials to facilitate new and unprecedented designs of microwave components, unique sensors, and revolutionary biomimetic devices such as tissue scaffolding.

	FY 2007	FY 2008	FY 2009
Engineered Bio-Molecular Nano-Devices and Systems	3.112	3.032	10.733

(U) The Engineered Bio-Molecular Nano-Devices and Systems 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. This program will also develop novel nanomaterials for exquisitely precise purification of materials, enabling such diverse applications as oxygen generation and desalination.

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated that a sensor element composed of a single protein molecule could be packaged and sustained for greater than one week, an order of magnitude improvement over the previous state-of-the-art.
- Demonstrated new sensor architecture that promises accurate detection of toxic agents while reducing false positive detections due to interferents present in the environment.

FY 2008 Plans:

- Demonstrate detection of nerve agents at established thresholds.
- Demonstrate acceptable false alarm signals in the presence of interferents.
- Begin design and prototyping of a multi-element (5) array of sensor elements.

FY 2009 Plans:

- Develop a 50-element array able to resolve mixtures of more than five components with a probability of detection >99% and false alarm rate of <1/1000.
- Design new nano-level circuit devices and adaptive/structural material systems via a priori topological mathematical computation.
- Develop new materials to replace silicon for ultra-dense and miniaturized electronic devices, and develop liquid state electronics.
- Develop new tunable materials that possess novel transport properties, such as mass and charge separation.

	FY 2007	FY 2008	FY 2009
Atomic Scale Materials and Devices	8.100	13.500	12.500

(U) This thrust examines the fundamental physics of materials at the atomic scale in order to develop new devices and capabilities. A 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. In addition, this program will examine other novel classes of materials and phenomena such as plasmons or Bose-Einstein Condensates (BEC) that have the potential to provide new capabilities in the quantum regime, for example, GPS-independent navigation via atom interferometry.

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(U) Program Plans:

FY 2007 Accomplishments:

- Developed theory for achieving nonlinear effects and/or gain in plasmonic structures.
- Achieved 40,000 BEC atoms/pulse every five seconds with 1.2 second BEC lifetime, enabling a 10x improvement in measurement rate.
- Completed baseline design of cold-atom optical lattice experiments.

FY 2008 Plans:

- Develop potential applications of plasmonics for on-chip optoelectronic coupling.
- Demonstrate Rubidium atomic clock with line-width below 10 Hz (less than 10% natural line-width).
- Demonstrate high-throughput optical lattice systems for improved simulation time and stable frequency metrology.

FY 2009 Plans:

- Demonstrate, in a military relevant application, the advantage of plasmonics for exploiting the high information carrying capacity of optics with the size advantages of electronics.
- Demonstrate rotationally sensitive interferometer with sensitivity greater than 1 radian per earth rotation rate.
- Emulate 2-D Bose-Hubbard Model phase diagram in under 12 hours that confirms theoretical calculations.

	FY 2007	FY 2008	FY 2009
Surface Enhanced Raman Scattering (SERS) - Science and Technology	0.000	5.000	8.000

(U) The Surface Enhanced Raman Scattering (SERS) – Science and Technology program focuses on the fundamental technical challenges facing potential sensor performance with respect to their sensitivity, selectivity, enhancement factors and development. SERS nanoparticles have considerable potential for both chemical and biochemical sensing applications due to: (1) their potential large spectral enhancement factors, (2) the nature of spectral fingerprints that can be expected to yield low false alarm rates, and (3) the capability for detecting targeted molecules at useful stand-off ranges. This program seeks to identify and overcome the key scientific and technical challenges necessary for replacing existing sensors of chemical and biological warfare (CBW) agents with SERS-based sensing approaches.

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(U) Program Plans:

FY 2008 Plans:

- Develop understanding of nanoparticle shape and its effect on SERS enhancements; examine high quality resonators for SERS applications.

FY 2009 Plans:

- Develop methods to engineer nanoparticles with 1 nanometer feature sizes (separation) on a macroscale.

	FY 2007	FY 2008	FY 2009
Quantum Sensors	3.000	4.800	0.000

(U) The Quantum Sensors program is developing approaches to exploit non-classical effects called entanglement to improve the resolution and range of military sensors. Quantum sensors will retain the generally better propagation characteristics of long wavelength light while achieving the better spatial resolution of short wavelength radiation. Conventional classical sensors rely on light with shorter wavelengths, like blue light, to produce sharp images. As wavelengths increase, for example from blue to infrared, the classical resolution decreases. Quantum sensors will be able to retain high resolution as the wavelength increases using a non-classical effect called entanglement. Two broad classes of sensor are under consideration. Type I quantum sensors propagate entangled photons to a target and back to a detector, where quantum effects may enhance resolution. Type II quantum sensors propagate classical radiation to the target, and entangled photons are used within the detector to improve resolution. A third class of approach, based on ghost imaging, is also being explored. As the program transitions from the theoretical proof stage to the subsystem design stage in FY 2009 it will move to the Electronic Technology PE 0602716E, Project ELT-01.

(U) Program Plans:

FY 2007 Accomplishments:

- Commenced experimental measurements to determine whether non-classical quantum states can be propagated through the atmosphere.
- Developed theoretical paradigm for absorption by one class of entangled photon states.

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FY 2008 Plans:
- Continue studies of Type I, Type II, and ghost imaging sensor concepts to establish whether they are robust to military targets and environments.
- Complete experiments on outdoor propagation of non-classical states.

	FY 2007	FY 2008	FY 2009
Comparative Genomics for National Security Goals	1.650	1.000	0.000

(U) Program Plans:
FY 2007 Accomplishments:
- Verified new approaches for examining prognostic epidemiology using comparative genomics.

FY 2008 Plans:
- Continue to examine prognostic epidemiology using comparative genomics.

	FY 2007	FY 2008	FY 2009
Advanced Materials Research Institute	2.200	4.000	0.000

(U) Program Plans:
FY 2007 Accomplishments:
- This effort focused on the development and demonstration of hybrid sensors for chemical and/or biological agent detection for national security. In particular, sensors made from metal oxide nanoparticles and nanowires were explored.

FY 2008 Plans:
- Investigate use of nanoparticles and nanowires to improve chemical electron mobility and/or magnetic energy storage product relative to bulk materials.

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

	FY 2007	FY 2008	FY 2009
Next Generation Protective Gear for Small Arms Threats	1.000	0.000	0.000

(U) Program Plans:
FY 2007 Accomplishments:
– Explored next generation protective gear for small arms threats.

	FY 2007	FY 2008	FY 2009
Alternative Futures at the Range-Complex Level for the Southwest U.S.	0.000	1.000	0.000

(U) Program Plans:
FY 2008 Plans:
– Explore alternative Range-Complex Level Futures in the Southwestern part of the U.S.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)						DATE: February 2008	
APPROPRIATION/BUDGET ACTIVITY: RDT&E, Defense-wide; BA2 Applied Research			R-1 ITEM NOMENCLATURE: Information and Communications Technology; PE 0602303E				
COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	228.073	230.385	254.009	234.676	203.437	201.456	201.454
High Productivity, High-Performance Responsive Architectures IT-02	84.927	65.913	98.641	85.764	67.360	67.360	67.359
Information Assurance and Survivability IT-03	72.607	93.049	80.349	76.479	83.484	81.503	81.502
Language Translation IT-04	70.539	71.423	75.019	72.433	52.593	52.593	52.593

(U) Mission Description:

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

(U) The High Productivity, High-Performance Responsive Architectures project is developing high-productivity, high-performance computing hardware and the associated software technology base required to support future critical national security needs for computationally-intensive and data-intensive applications. These technologies will lead to new multi-generation product lines of commercially viable, sustainable computing systems for a broad spectrum of scientific and engineering applications; it will include both supercomputer and embedded computing systems.

(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.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E

(U) The Language Translation project will develop and test powerful new Human Language Technology that will provide critical capabilities for a wide range of national security needs. This technology will enable systems to a) automatically translate and exploit large volumes of speech and text in multiple languages obtained through a variety of means; b) to have two-way (foreign-language-to-English and English-to-foreign-language) translation; c) enable automated transcription and translation of foreign speech and text along with content summarization; and d) enable exploitation of captured, foreign language hard-copy documents.

(U) **Program Change Summary:** *(In Millions)*	**FY 2007**	**FY 2008**	**FY 2009**
Previous President's Budget	234.065	229.739	284.646
Current Budget	228.073	230.385	254.009
Total Adjustments	-5.992	0.646	-30.637
Congressional program reductions	0.000	-1.474	
Congressional increases	0.000	2.120	
Reprogrammings	0.000		
SBIR/STTR transfer	-5.992		

(U) Change Summary Explanation:

FY 2007	The decrease reflects the SBIR/STTR transfer.
FY 2008	The increase reflects reductions for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions, offset by congressional adds National Repository of Digital Forensic Intelligence and Software Assurance Education and Research Institute.
FY 2009	The decrease reflects program re-phasing primarily in the Information Assurance and Survivability project, IT-03.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)						DATE February 2008	
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research			R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, Project IT-02				
COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
High Productivity, High-Performance Responsive Architectures IT-02	84.927	65.913	98.641	85.764	67.360	67.360	67.359

(U) Mission Description:

(U) The High Productivity, High-Performance Responsive Architectures project is developing high-productivity, high-performance computer hardware and the associated software technology base required to support future critical national security needs for computationally-intensive and data-intensive applications. These technologies will lead to new multi-generation product lines of commercially viable, sustainable computing systems for a broad spectrum of scientific and engineering applications; it will include both supercomputer and embedded computing systems. The project will ensure accessibility and usability to a wide range of application developers, not just computational science experts. This project is essential for maintaining the nation's strength in both supercomputer computation for ultra large-scale engineering applications and for surveillance and reconnaissance data assimilation and exploitation.

(U) One of the major challenges currently facing the DoD is the prohibitively high cost, time, and expertise required to build large complex software systems. Powerful new approaches and tools are needed to enable the rapid and efficient production of new software, including software that can be easily changed to address new requirements and can adjust dynamically to platform and environmental perturbations.

(U) Even as this project develops the next generation of high-productivity, high-performance computing systems, it is looking further into the future to develop the technological and architectural solutions that are required to develop "extreme computing" systems. The military will demand increasing diversity, quantities, and complexity of sensor and other types of data, both on the battlefield and in command centers - processed in time to effectively impact warfighters' decisions. Computing assets must progress dramatically to meet significantly increasing performance and significantly decreasing power and size requirements. Extreme computing systems will scale to deliver a thousand times the capabilities of future petascale systems using the same power and size or will scale to deliver terascale-embedded systems at one millionth of the size and power of petascale systems. The resulting extreme computing systems will be capable of scaling from embedded to leadership class systems. The most significant technical achievements that must be realized to obtain the goals of extreme computing are the enabling architectural advancements, pervasive low power technologies, and low volume physical packaging of these systems. Numerous additional technical challenges must be resolved, including the reliability of "extreme computing" systems: embedded systems require a higher level of reliability and assurance than general-purpose systems because the failure of an embedded computing system can result in the loss of a deployed platform.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, Project IT-02

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
High-Productivity Computing Systems	77.952	47.243	71.654

*Previously part of Responsive Computing Architectures

(U) The ongoing High-Productivity Computing Systems (HPCS) program will enable nuclear stockpile stewardship, weapons design, cryptanalysis, weather prediction, and other large-scale problems that cannot be addressed productively with today's computers. The goal of this multi-agency program is to develop revolutionary flexible and well-balanced computer architectures that will deliver high performance with significantly improved productivity for a broad spectrum of applications.

(U) It is extremely difficult to program today's high-performance computers; even for expert programmers, these systems present a significant challenge. The programming of such large systems must be made much easier so that programmers and scientists with minimal computer skills can harness the power of high-performance computers. As the number of processors increases to 100,000 and beyond, it is difficult not only to develop application codes, but also to debug and optimize them, since tools that will help are designed for small-scale systems (10's of processors). This area of user productivity is where HPCS is focusing significant effort. The HPCS technology development plan is being executed in three phases that will extend to the end of this decade. The three phases are (I) concept design study, (II) research and development, and (III) system development, resulting in large-scale prototypes.

(U) Initiated in 2002, the DARPA HPCS program is responsive to a strategy developed in conjunction with the U.S. National Security Community. The ultimate goal of the HPCS program is to create a new generation of economically viable high productivity computing systems for the national security and industrial user communities. High productivity computing is a key technology enabler for meeting our national security and economic competitiveness requirements. In November 2006, the HPCS program moved into the third and final phase, with a down-select from three vendors to two. In Phase III of the HPCS program, the two remaining vendors will complete the designs and technical development of very large (petascale) productive supercomputers, with demonstration of prototype systems in 2010-2011. DARPA funding is sufficient to cover the contractual requirements of one of the two selected vendors. NSA and DOE, partners with DARPA in this program, provide funding to enable maintaining a second vendor in the program.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, Project IT-02

(U) Program Plans:

FY 2007 Accomplishments:

- Performed a down-select from the three HPCS Phase II participants to two Phase III participants.
- Initiated prototype development (Phase III) of two high-end high-productivity petascale computing systems.
- Initiated high-level design of key application-specific integrated circuits (ASICs) and development of hardware simulators.
- Performed research and development on parallel programming languages and/or development environments that will increase user productivity on HPCS systems, and released early versions of the languages to HPCS stakeholders.

FY 2008 Plans:

- Complete design verification of most ASICs: a critical step before releasing design to the very costly fabrication process.
- Develop and implement operating system scaling and performance improvements so that existing operating systems can be leveraged, saving development costs, facilitating use of legacy code, and improving user productivity by preventing the need to learn a new operating system.
- Demonstrate early versions of productivity tools for the HPCS stakeholders to solicit their feedback.
- Continue developing productivity tools.
- Conduct an HPCS software critical design review of each vendor.
- Vendor delivery of HPCS system design specifications for evaluation by the government.
- Explore opportunities to expand the user base for high-end computing.

FY 2009 Plans:

- Release of the beta version application development software to HPCS stakeholders for evaluation and provide familiarity with the software prior to system release thus reducing the learning curve upon system availability.
- Fabricate and test several of the ASICs.
- Continue to develop and implement operating system scaling and performance improvements.
- Continue developing productivity tools.
- Conduct critical design review of each HPCS vendor’s system.
- Begin porting applications to a subset of the actual HPCS prototype hardware in preparation for FY 2010 subsystem demo that will provide evidence that the full prototype system will meet its productivity and performance goals.

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	FY 2007	FY 2008	FY 2009
Software Producibility	6.975	10.600	15.996

*Previously part of Responsive Computing Architectures.

(U) The Software Producibility program will reduce the cost, time, and expertise required to build large complex software systems. This includes new techniques for rapidly developing adaptive software that can be easily changed to conform to new software design and development tools, readily complies to new requirements, and readjusts dynamically to environmental perturbation. Today, production-quality compilers are developed at significant cost for a defined class of systems regardless of the actual system resources available to and/or needed by an application. This places significant programming burden on developers when creating applications who must consider the platform and its applications. Improvements in compiler technology can greatly simplify application development by providing the capability to automatically and efficiently generate a compiler that reliably executes a broad spectrum of military and industrial applications for target computing systems that range from a single multi-core processor system to very large multi-processor systems. Military systems critically depend on complex software that is reliable, robust, and secure. Mature software frameworks (e.g., Apple Cocoa, Microsoft Foundation Class library, Java Swing, JBOSS, SDL, etc.) provide well tested and well-considered mechanisms that, if used properly, can enable developers to quickly create sophisticated applications of high quality. But designers/developers have a very steep learning curve when working in a new framework. A combination of fundamental software analysis and tool assistance can enable software developers to function effectively at the expert level in multi-framework environments but without the excessive investments of time required by current techniques.

(U) Program Plans:

FY 2007 Accomplishments:

- Formulated a strategy for achieving software producibility through adaptivity.
- Identified challenge problems, in the flight control system and software radio domains, for evaluating new adaptive software techniques.
- Identified candidate strategies for rapidly employing existing, mature, software frameworks to speed new system construction.

FY 2008 Plans:

- Develop toolchains to support preliminary flight control/vehicle management system and software defined radio experiments.
- Conduct a fault management design time experiment.

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- Conduct a software defined radio design time and load time adaptation experiments.
- Investigate an initial concept for characterization tools and self-assembling compiler elements.

FY 2009 Plans:

- Develop toolchains to support optimized verification, field update and security adaptation experiments.
- Conduct optimized verification, field update and security adaptation experiments.
- Create the initial common development environment and supporting technologies that will allow efficient application development, implementation, and execution on heterogeneous computer architectures.
- Develop inter-framework mappings and other techniques to make software expertise more portable to the "next" required framework.
- Develop tools and techniques that enable software developers to perform at the expert level in multiple complex software frameworks simultaneously.

	FY 2007	FY 2008	FY 2009
Extreme Computing *	0.000	8.070	10.991

*Previously part of Responsive Computing Architectures.

(U) The Extreme Computing program will enable ExaScale computing systems in the post-2010 timeframe, with processing that will exceed one quintillion (10^18) operations (floating point, fixed point or data movement), per second. Significant technical roadblocks to scalable performance, productivity, physical size, power, and programmability must be overcome to realize the goals of extreme computing. As Moore's law reaches its limit, we can no longer depend on significantly increasing clock rates for performance advances. Current and evolutionary bandwidth and latency of data movement operations and current data placement approaches will not be sufficient to sustain anticipated or desired increases in processing performance. It will be essential to find new techniques that minimize data movement and optimize data communication performance.

(U) Ensuring dramatic advances in processing performance is critical as the amount and type of raw data needing to be turned into actionable information rapidly escalates. Previously, advances in commercial off-the-shelf (COTS) systems have addressed these needs but future COTS processors are ill-suited for developing military requirements because they are increasingly less productive for military applications, are power-

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hungry, and limit the performance available to the warfighter. To support escalating processing needs both at the embedded and supercomputer level, completely new architectures at the processor/memory/data movement and system level are needed to enable extreme computing.

(U) Another critical research area will develop self aware, self optimizing processing system approaches. Within the context of DoD systems, mechanisms for self-modification will enable systems to adapt in real-time to changing requirements, faults, and malicious attacks. Research in self-aware trusted computing will develop the capabilities to provide autonomous system monitoring and optimization, ensuring the necessary processing system adaptations are transparent to the operator. Self-monitoring hardware in conjunction with co-developed software will incorporate cognitive techniques to determine the state, performance, and health of the processing system, and based on the processing system's self-evaluation, will reconfigure to provide optimized system performance.

(U) Program Plans:

FY 2008 Plans:

- Identify and assess the potential technologies necessary to provide the types of improvements essential to achieve extreme computing: non-von Neumann architectures; 3-D microelectronic structures; high bandwidth/low latency electrical and optical technologies, multiple-core processors; radically different packaging solutions; new memory and storage architectures; and non-intrusive interfaces.
- Formulate new processor and memory architectures that will lead to extreme computing.
- Initiate a study to identify potential new hardware architectures and candidate approaches, such as master/slave methods where the "slave" collects and condenses data.
- Develop initial concepts for, and evaluate the feasibility of computational architectures and computing systems that monitor execution at run time, and dynamically optimize performance (e.g., with respect to caching, on-chip packet routing, etc.) on common applications.

FY 2009 Plans:

- Develop the identified critical technologies, processor technologies, system methodologies, and architectures to enable general-purpose and embedded computing systems to perform at exascale levels and beyond and enable significantly improved and new capabilities to the warfighter.
- Explore, develop, evaluate and perform initial simulations of techniques to enable computing systems to self-monitor their state, identify unexpected or unwanted system behavior, marshal processing resources to optimize performance, and transparently adapt in real time.

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– Establish initial coordination with selected DoD applications for self-aware/self-optimizing approaches to establish example DoD context and future transition opportunities.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, Project IT-03

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Information Assurance and Survivability IT-03	72.607	93.049	80.349	76.479	83.484	81.503	81.502

(U) Mission Description:

(U) This project is developing the technology required to make emerging information system capabilities (such as wireless and mobile code/mobile systems) inherently secure, and to protect DoD's mission-critical systems against attack upon or through the supporting information infrastructure. These technologies will enable our critical systems to provide continuous correct operation even when they are attacked. The technologies will also lead to generations of stronger protection, higher performance, and more cost-effective security and survivability solutions scalable to several thousand sites. Technologies developed under this project will be exploited by all the projects within this program element, and those in the Command, Control, and Communications program element (PE 0603760E), the Network-Centric Warfare Technology program element (PE 0603764E), the Sensor Technology program element (PE 0603767E), the Guidance Technology program element (PE 0603768E), and other programs that satisfy defense requirements for secure, survivable, and network centric systems.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Next Generation Core Optical Networks (CORONET)	7.841	14.000	14.500

(U) The Next Generation Core Optical Networks (CORONET) program will revolutionize the operation, performance, security, and survivability of the United States' critical inter-networking system by leveraging technology developed in DARPA photonics component and secure networking programs. These goals will be accomplished through a transformation in fundamental networking concepts that form the foundation upon which future inter-networking hardware, architecture, protocols and applications will be built. Key technical enablers that will be developed in this thrust include: (1) network management tools that guarantee optimization of high density wavelength-division-multiplexed optical channels, such as those provided by wavelength division multiplexing; (2) 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 (3) demonstration of novel concepts in applications such as distributed and network based command and control, intelligence analysis, predictive logistics management,

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simulation and scenario enhanced decision-making support for real-time combat operations, and assured operation of critical U.S. networking functions when faced with severe physical layer attack. These network-based functions will support the real-time, fast-reaction operations of senior leadership, major commands and field units.

(U) A complimentary effort, the Transmission, Switching and Applications for Next-Generation Core Optical Networks program will develop the technology and applications to realize the next-generation dynamic multi-terabit networks that can deliver advanced internet protocol and optical services. This will be accomplished by: (1) greatly increasing network capacity through the use of more efficient fiber-optical transmission techniques; (2) implementing agile, high capacity, all optical switching platforms, and (3) developing the software and hardware interfaces, as well as the migration strategy, to enable new applications that can take full advantage of dynamic multi-terabit core optical networks.

(U) Program Plans:

– Next Generation Core Optical Networks (CORONET)

FY 2007 Accomplishments:

-- Completed an extensive economic study of all-optical bypass and grooming at the core and the edge of a global fiber-optic network.

-- Completed a study of the capacity limits of digital, wavelength-division-multiplexed (WDM) fiber-optic transmission systems, which showed the potential for more than ten-fold increase in the capacity per fiber compared to today's systems.

-- Completed a study of analog WDM fiber-optic transmission systems, which showed that such analog systems are limited to distances of several tens of kilometers. Thus they are not suitable for core optical networks of national or global extent.

FY 2008 Plans:

-- Develop the architectures and define the network elements for a fast reconfigurable optical core network.

-- Develop protocols, algorithms and the network control and management architecture to provide fast service setup, fast restoration from multiple network failures and guaranteed quality of service for a global core optical network.

FY 2009 Plans:

-- Model and simulate a dynamically reconfigurable multi-terabit global core optical network.

-- Initiate the development of the network control and management software such that the final product will be transitioned and implemented in current commercial and DoD core optical networks.

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– Transmission, Switching and Applications for Next-Generation Core Optical Networks
FY 2007 Accomplishments:
-- Completed a study to determine the capacity limits of modern fiber telecommunications.
FY 2008 Plans:
-- Complete a study on the use of "Maximum Likelihood Sequence Estimation", to increase the spectral efficiency of existing optical networks by up to ten times.
-- Complete a study to determine the impacts of emerging 100 Gbps Ethernet technology on next-generation optical networks.
-- Initiate a study to examine migration strategies and associated software and hardware interfaces to enable new applications for next-generation core optical networks.
FY 2009 Plans:
-- Develop and demonstrate an efficient fiber-optical transmission technique to enable several-fold increase in fiber capacity.
-- Develop architecture design and fabrication of a multi-terabit all-optical switch capable of fast switching of wavelengths and of sub-wavelength grooming.
-- Develop the software and hardware interfaces, as well as the migration strategy, to enable new applications that can take full advantage of dynamic multi-terabit core optical networks.
-- Initiate a national-scale multi-terabit network testbed to test and demonstrate hardware, software and applications of next-generation core optical networks.

	FY 2007	FY 2008	FY 2009
Dynamic Quarantine of Computer-Based Worms	25.201	12.343	10.932

(U) The goal of the Dynamic Quarantine of Computer-Based Worms program is to develop defenses for U.S. military networks against large-scale malicious code attacks such as computer-based worms. As the U.S. military pushes forward with network-centric warfare, terrorists and other nation-states are likely to develop and employ self-replicating malicious code to impede our ability to fight efficiently and effectively. This program will develop the capability to automatically detect and inoculate DoD networks against never before seen computer worm attacks. This program will also assess the comparative strength of different architectural solutions.

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(U) The DCAMANET program developed and refined technologies for Defense Against Cyber Attacks on Mobile Ad-hoc Network Systems (DCAMANETS). This effort researched, prototyped, and evaluated defenses that sensed failures and attacks on military tactical wireless networks and auto-reconfigured in real-time to provide continuous service of mission-critical activities. The next step of the DCAMANET program will be to develop an intrinsically assurable mobile ad-hoc network. An intrinsically assurable mobile ad-hoc network will directly support integrity, availability, reliability, confidentiality, and safety of MANET communications and data. In contrast, the dominant Internet paradigm is intrinsically insecure. For example, the Internet does not deny unauthorized traffic by default and therefore violates the principle of least privilege. In addition, there are no provisions for non-repudiation or accountability and therefore adversaries can probe for vulnerabilities with impunity because the likelihood of attributing bad behavior to an adversary is limited. Current protocols are not robust to purposely induced failures and malicious behavior, leaving entire Internet-based systems vulnerable in the case of defensive failure.

(U) Program Plans:

– Dynamic Quarantine of Computer-Based Worms

FY 2007 Accomplishments:

-- Completed two prototype systems utilizing divergent methodologies.
-- Strenuously tested prototypes against self-replicating malicious code on simulated operational networks.
-- Refined prototypes automatic detection and quarantine mechanisms and prepared for further testing that will encompass nation-state level of worm attacks.

FY 2008 Plans:

-- Develop requirements to integrate system into DoD enterprise networks.
-- Integrate Defense Quarantine of Computer Based-Worms (DQW) prototype into DoD enterprise solution tool suite.
-- Harden system against directed attacks.
-- Conduct operational test of representative integrated system against full-spectrum nation state worm threat.
-- Test integrated system on operational representative network.

FY 2009 Plans:

-- Test integrated system against red teams (attack teams) during combatant command exercise.
-- Commence technology transition to DoD.

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– Defense Against Cyber Attacks on MANETS (DCAMANETS)
FY 2007 Accomplishments:
-- Prototyped, tested, and evaluated three DCAMANETS solutions.
-- Developed an automated mobile wireless testbed that emulates operational environments.
-- Developed and tested host-based and network-based detection and quarantine sensors/actuators for MANET systems.
FY 2008 Plans:
-- Research and develop techniques for authenticating and accounting for the use of all MANET resources.
-- Research and develop methods for denying all but authorized MANET traffic.
-- Research and develop methods for tolerating purposely induced failures from one or more MANET nodes and applications.
FY 2009 Plans:
-- Prototype and evaluate a combined assurable MANET infrastructure.
-- Research and prototype a secondary defensive system.

	FY 2007	FY 2008	FY 2009
Trustworthy Systems	4.408	12.800	10.000

(U) The goal of the Trustworthy Systems program is to provide foundational trustworthy computer platforms for Defense Department computing systems. This program seeks to develop technologies such as novel computer processing architectures, hardware, firmware, or microkernels to guarantee network and workstation security and will initially focus on network-based monitoring approaches that provide maximum coverage of the network with performance independent of the network size. These technologies will protect Defense systems from a wide-range of software problems, ranging from worms and Trojan horses, to bug-ridden software. This effort will focus on the development of feedback control-based solutions to software vulnerabilities and gateway-and-below network traffic monitoring approaches that scale with network size. The design of the controller component will leverage virtual machines to provide hardware-equivalent protection for the controller that specifically monitors the trustworthiness state of the application of interest, map the observations to a model of trustworthiness for that application, then decide what, if any, control actions need to be taken. Operational goals of the network-monitoring component include (1) improved probability of detection/probability of false alarm performance and (2) scalability to future gateway line speeds. The desired result is to allow software to be imperfect while mitigating catastrophic failures. Technical challenges include remotely monitoring mission-critical servers using

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virtual machines, tracking the trustworthiness of the server, and controlling the server to return it to trustworthiness states. Primary end users identified to date include STRATCOM JTF/GNO and HQ PACOM. Transition partners include NCSC, NIWA, and DISA.

(U) Program Plans:

FY 2007 Accomplishments:

- Enabled the ability to detect and respond to next generation malicious software including stealthy "backdoors" to the operating system kernel (rootkits) and networks of compromised computers.
- Developed tools to find vulnerabilities in complex open source software.
- Surveyed state-of-art in virtual machine software technology.
- Evaluated capabilities of closed-feedback system for automated recovery of corrupted systems.

FY 2008 Plans:

- Develop scalable formal methods to verify complex hardware/software.
- Research network-sensitive approaches to monitor, and trustworthy controllers to control, how and when information is disseminated across the network based on network performance, load, criticality, and target capacity.
- Investigate the use of new virtual machine hardware architectures to develop a feedback loop that enables the host to monitor and control its behavior in the presence of untrustworthy software.
- Investigate secure hardware designs, software architectures, and code assessment technologies.
- Evaluate client-side controller software in laboratory environment.

FY 2009 Plans:

- Develop client-side laboratory-scale software and server-side virtual-machine based automated recovery.
- Harden and evaluate client-side controller code for field-deployable operations.
- Research network-sensitive approaches to monitor how and when information is disseminated across the network based on network performance, load, criticality, and target capacity.
- Develop high-throughput sensors, low-latency collection networks, and high-speed analyzers to assimilate the data.

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	FY 2007	FY 2008	FY 2009
DARPA Future Information Assurance Initiatives	3.878	8.250	0.000

(U) The DARPA Future Information Assurance Initiatives will identify promising technologies to enable remote command, control, communications, computers, intelligence, surveillance, and reconnaissance (C^4ISR) warfighting. Sophisticated computing capabilities currently available in desktop workstation and server systems are moving to mobile wireless embedded systems that communicate over low-bandwidth self-organizing tactical networks. As a result, the spectrum of devices the U.S. military must protect is increasing from wired and wireless tactical and garrison computers to include a wide array of small mobile devices. With foreign production of information technology components increasing and adversaries seeking to leverage 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 effective cyber attacks while reducing the manpower required. Other distinct programs within this project will be created to pursue promising technologies as they are identified for further focused development. Included in this initiative is the development of secure, efficient network protocols to exploit tomorrows network-centric technologies such as networked weapons platforms, mobile ad-hoc networks, and end-to-end collaboration (vice client-server paradigm).

(U) Program Plans:

FY 2007 Accomplishments:

- Developed automatic techniques to modify computer applications to add information assurance properties (e.g. confidentiality, authentication, and others).
- Developed the ability to protect the core signaling and control of converged networks running voice over internet protocol (VOIP), wireless, voice, and data networks in enterprise telecommunications.
- Developed the ability to identify and authenticate hosts on the network and allow these hosts to discover their network's operating attributes.

FY 2008 Plans:

- Develop a family of distributed, autonomous security devices to deal with asymmetric traffic on wide area networks.
- Develop a secure, efficient network routing protocol for tomorrow's weapon, logistic, and command and control requirements.
- Develop a wireless protocol that securely provides location, authentication, and communications in a practical manner.
- Investigate new approaches to network security that scale with increased data rates and address spaces of future networks.

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	FY 2007	FY 2008	FY 2009
Control Plane	7.709	7.296	5.500

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

(U) Program Plans:

FY 2007 Accomplishments:

- Initiated development of hardware and software mechanisms to improve end-to-end wide-area network performance between the CONUS operating base and forward deployed tactical units.

FY 2008 Plans:

- Complete development of hardware and software mechanisms to improve end-to-end wide-area network performance between the 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 transition partners through network query protocols.
- Investigate authentication protocols for secure transmission of network performance information.
- Develop the ability of hosts to learn about more than one possible transmission path, other hosts' abilities and purpose, and form communities of interest which suits their collective needs best.
- Develop the ability of hosts to simultaneously use multiple network paths for the same data transmission with the same partner, increasing communications speed and reliability.

FY 2009 Plans:

- Conduct demonstrations in operationally relevant environments.
- Demonstrate overall network transmission speed up to 60 Gbps using multiple fibers simultaneously.

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– Transition Control Plane technology to the Services.

	FY 2007	FY 2008	FY 2009
Wide Area Network (WAN) Monitoring	2.256	3.000	0.000

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

(U) Program Plans:

FY 2007 Accomplishments:

– Researched high-throughput hardware to implement the algorithms at the sensor layer.
– Investigated low-latency networks to collect the information.
– Investigated high-speed analyzers to assimilate the data and detect perturbations.

FY 2008 Plans:

– Investigate algorithms that quickly characterize various host's security configurations, identity, and classification as well as measure the type and quantity of information exchange.
– Analyze technologies to synthesize and visualize extremely large networks to improve leadership's situational awareness at the enterprise level.
– Research integrating and testing components in a fully functional configuration.

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	FY 2007	FY 2008	FY 2009
Spread Spectrum Networking	1.100	5.000	0.000

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

(U) Program Plans:

FY 2007 Accomplishments:

- Modeled the problem of protecting wireless communications against cross-layer denial-of-service attacks with a game-theoretic approach.
- Demonstrated the performance of the spread spectrum networking approach for protection against smart attacks.

FY 2008 Plans:

- Investigate efficient smart-jammers against a communication system and developed countermeasures based on the Spread Spectrum approach.
- Document spread spectrum networking lessons learned.

	FY 2007	FY 2008	FY 2009
Control-Based Mobile Ad-Hoc Networks (CBMANET)	9.199	11.560	12.500

(U) The Control-Based Mobile Ad-Hoc Networks (CBMANET) program is developing an adaptive networking capability that dramatically improves performance and reduces life-threatening communication failures in complex communication networks. In order to develop this new capability, the initial focus is on tactical mobile ad-hoc networks (MANETs) that are inadequately supported with commercial technology.

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Conventional MANETs are composed of interdependent nodes based on interdependent system layers. Each MANET node exposes tens to hundreds of configurable parameters that must be continuously adapted due to variable tactical factors such as mission profile, phase, force structure, enemy activity, and environmental conditions. The complexity of this high-dimensional, adaptive, constrained, distributed network configuration problem is overwhelming to human operators and designers and has root causes in the historically wire-line-oriented networking paradigms. This program will take on the ambitious goal of researching a novel protocol stack that supports integrated optimization and control of all network layers simultaneously. Key technical challenges include scalable design, stability, and convergence. These challenges are particularly difficult in a distributed setting with partial and uncertain information, high communications overhead, and high probability of link failure. To address this problem, the CBMANET program will exploit recent optimization-theoretic breakthroughs, recent information-theoretic breakthroughs, and comprehensive cross-layer design to develop a network stack from first principles with specific attention to support for DoD applications such as multicast voice and situation awareness.

(U) Program Plans:

FY 2007 Accomplishments:

- Designed and prototyped two novel network protocol architectures based on information theory and optimization theory.
- Designed and analyzed protocols based on network coding that vastly improve performance in extreme conditions.
- Designed and analyzed cross-layer protocols and adaptive control capabilities to drive resource allocation more efficiently.
- Performed quantitative analysis and trade studies to understand the degree of performance offered by two novel network architectures.
- Researched requirements for a radio hardware platform to optimally support the novel network stacks.

FY 2008 Plans:

- Demonstrate and evaluate both technologies in realistic DoD scenarios using modeling and simulation.
- Design appropriate interfaces between the CBMANET network stacks and the physical radios in support of cross-layer optimization.
- Integrate the novel network architectures with physical radios in preparation for field demonstrations.

FY 2009 Plans:

- Undertake field demonstrations in challenging tactical environments.
- Research integrated coding and backpressure-based quality of service.
- Transition activities to the Services.

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	FY 2007	FY 2008	FY 2009
Security-Aware Systems	11.015	16.680	14.000

(U) The Security-Aware Systems program will develop and advance a variety of potentially promising technologies to enable the military to field secure, survivable, self-monitoring, self-defending network centric systems. Today's military software systems are brittle in the face of changing requirements. They are vulnerable to skilled attackers who develop creative and unpredictable strategies. Misconfiguration accounts for most security failures in Internet services and poses a serious risk to military systems. This program will develop security aware systems that will avoid brittleness and vulnerability, due to their ability to reason about their own security attributes, capabilities and functions with respect to specific mission needs. These systems will also dynamically adapt to provide desired levels of service while minimizing risk and providing coherent explanations of the relative safety of service level alternatives. These systems will bolster the reliability and security of critical open source software systems by reducing vulnerabilities and logic errors, and providing state-of-the-art software analysis techniques augmented with cognitive decision-making techniques with the ultimate goal of applying these systems on to the Global Information Grid. The Security-Aware Systems program consists of two efforts, Applications Communities (AC) and Self-Regenerative Systems (SRS).

- The Application Communities (AC) effort will develop technologies to protect DoD information systems that employ commercial software applications against cyber attack and system failure by developing collaboration-based defenses that detect, respond to, and heal with little or no human assistance. The effort will leverage advances in information assurance research programs to create a new generation of self-defending software that automatically responds to threats, and provides a comprehensive picture of security properties, displayed at multiple levels of abstraction and formality. This capability will bring intelligent security adaptation to DoD systems and make security properties and status more apparent to decision makers. AC technology will enable collections of similar systems to collaboratively generate a shared awareness of security vulnerabilities, vulnerability mitigation strategies, and early warnings of attack. AC will revolutionize the security of military information systems and reduce the threat from stealthy intrusion of critical systems and/or denial of service attacks.

- The Self-Regenerative Systems (SRS) effort will design, develop, demonstrate and validate architectures, tools, and techniques for fielding systems capable of adapting to novel threats, unanticipated workloads and evolving system configurations. SRS technology development of this effort will employ innovative techniques like biologically-inspired diversity, cognitive immunity and healing, granular and scalable redundancy, and higher-level functions such as reasoning, reflection and learning. SRS technologies will make critical future

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information systems more robust, survivable and trustworthy. SRS will also develop technologies to mitigate the insider threat. SRS-enabled systems will be able to reconstitute their full functional and performance capabilities after experiencing accidental component failure, software error, or even an intentional cyber-attack. These systems will also show a positive trend in reliability, actually exceeding initial operation capability and approaching a theoretical optimal performance level over long periods while maintaining robustness and trustworthiness attributes.

(U) Research efforts will also explore workstation-class systems (including "trusted systems") which at present do not provide provable separation of information at different security levels, or provable protection of high-integrity applications from low-integrity applications. A new kind of computer workstation is needed whose architecture enables both formal proof and exhaustive validation of critical information and program separation properties (e.g., information in one graphical user interface (GUI) window never leaks to another GUI window).

(U) Program Plans:

FY 2007 Accomplishments:

- Developed an Application Community (AC) system architecture and demonstrated a working prototype that showed learning of program behavior that can be used to protect and repair software systems.

FY 2008 Plans:

- Develop techniques to collaboratively diagnose and respond to problems (e.g., attacks or failures that threaten a mission) in groups of military systems.
- Develop techniques to summarize security policy and status so the descriptions produced by AC can be understood without omitting critical details.
- 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 additional general strategies to automatically immunize systems against new attacks and preempt insider attacks; enabling anomaly detection, combining and correlating information from system layers, and using direct user challenges.

FY 2009 Plans:

- Develop, test and validate regimes to assess the protection mechanisms of security products, and certify protection to quantifiable levels based on a scientific rationale.

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- Develop measures to quantitatively characterize various dimensions of security (availability, integrity, confidentiality, authentication, and non-repudiation), fault tolerance, and intrusion tolerance, and demonstrate the theory's relevance by applying it to a realistic exemplar system.
- Tailor an exemplar self-regenerative system representative of a military application, thereby demonstrating the protective value to the warfighter.
- Conceptualize a new computer workstation architecture that enables both formal proof and exhaustive validation of critical information and program separation properties.
- Formulate a "trust hierarchy" rooted at user-visible peripheral devices (mouse, keyboard, speakers, and display) and extending down to traditional kernel mechanisms and applications.

	FY 2007	FY 2008	FY 2009
Quantum Key Distribution over Wide-Area Fiber Optic Networks	0.000	0.000	3.000

(U) The prevailing method for securing information transmitted across DoD and Intelligence networks is through the use of end-to-end encryption. This requires frequent secure distribution of encryption keys across the network. Quantum key distribution could offer this capability across the network, resulting in enhanced security from eavesdropping, code-breaking and spoofing. The program's objective is to develop an end-to-end quantum key distribution capability that works over a wide-area fiber-optic network. Today, this technology has been demonstrated only for point-to-point connections over distances of less than 200 kilometers. A key technical challenge is to extend the quantum key distribution capability to national, or global, dynamically switched fiber-optic networks. The needed advancements to enable this are the creation of a "quantum repeater" and the development of the associated key distribution protocol. The goal of the program is to demonstrate this capability experimentally over an existing DoD wide-area test network.

(U) Program Plans:

FY 2009 Plans:

- Complete an analysis of quantum encryption over classic fiber-optic networks.
- Develop candidate technologies and protocols for quantum key distribution over global-scale fiber-optic networks.

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	FY 2007	FY 2008	FY 2009
System for Planning Information Operations and Nonkinetic Effectiveness (SPINE)	0.000	0.000	3.417

(U) The System for Planning Information Operations and Nonkinetic Effectiveness (SPINE) program will improve operational effectiveness, operational tempo, tool performance, tool development, decrease training requirements, enable scalable operations not possible today, and demonstrate the full potential of Information Operations (IO) capabilities due to their newly quantified performance metrics. The significant challenge is the development of models for non-kinetic weapons that are comparable to today's physics-based kinetic models. Those models are critical to demonstrating the effectiveness of non-kinetic weapons and configuring an IO range capable of collecting the diverse empirical data required to provide confidence in the measurements. The program will develop the following: first, measurement techniques to quantify the effectiveness of IO weapons; second, a planning system to give the combatant commander the ability to determine which combination of kinetic or non-kinetic weapons they should use during operations.

(U) Program Plans:
FY 2009 Plans:
- Develop algorithms/software to provide quantified metrics on Computer Network Attack tool performance.
- Expand tool suite to measure anticipated weapon performance based on known & estimated target network characteristics.
- Develop planning system that can select optimal course of action based on marriage of target configuration intelligence and quantified tool characteristics.

	FY 2007	FY 2008	FY 2009
Rootkit Detection	0.000	0.000	3.500

(U) Based on results from the Future Information Assurance program, Rootkit Detection will assess the current and emerging state-of-the-art rootkit (software tools intended to conceal running processes, files or system data from the operating system) technology, detection and mitigation in the context of the DoD and leverage experience with rootkits and detection and mitigation methods. After collecting rootkits and detection tools and methods, this program will establish knowledge of future rootkit trends and detection mechanisms. Technical goals include identifying trends

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in rootkit developments, anticipating next generation threats, and developing advanced detection and mitigation techniques. Possible approaches include: detection of indirect effects of rootkits (not implementation-specific effects), creation of abnormal usage conditions on the system to induce indirect effects, collection of evidence from multiple perspectives, and use of Bayesian Networks to reason over evidence. Comprehensive, objective and empirical data regarding the threat posed by rootkits, how well current approaches address that threat, characteristics and metrics for each approach and identification of (1) promising detection approaches and (2) key gaps. This program will address the growing threat of rootkits to DoD IT systems and networks.

(U) Program Plans:

FY 2009 Plans:

- Design and implement laboratory-scale automated rootkit detection and mitigation software.
- Evaluate developed software in laboratory environment.
- Harden laboratory-level code into field-deployable rootkit detection and mitigation system.
- Evaluate developed system in military information operations range.

	FY 2007	FY 2008	FY 2009
Defensive Autonomous Systems	0.000	0.000	3.000

(U) The Defense Autonomous Systems goal is to allow the military to more closely monitor and identify remotely-controlled computers (bots) and bot slaves within military and government networks, as well as increase the monitoring capability of our defenders. This program will develop novel software to enable this capability. Utilizing the border gateway protocol, this program will provide policy based routing between large pieces (i.e., autonomous systems) of the Internet. By building concentric rings from autonomous systems, it is possible to hide all or part of a network from people outside of the rings (e.g. on the Internet). By monitoring the interconnection points between the outer and inner ring, it is possible to identify all bot slaves and controllers because bot command and control traffic is fairly regular and has a unique signature. In order to monitor and mitigate against attacks from bot networks we must automate the tools we currently use. Adding the additional autonomous systems to existing military networks requires the military Services to request the new autonomous system, properly design and configure the interconnection, and monitor the system to detect an attack within minutes.

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(U) Program Plans:
FY 2009 Plans:
- Identify specific bot signatures and their uniqueness.
- Develop prototype mechanisms to test and evaluate this technique on military data networks.
- Design and implement laboratory-level automated detection, reverse engineering, and mitigation system.
- Modify existing router filters to identify bot traffic (or develop high-speed network devices if necessary).
- Develop a database for the routers (or the high-speed devices) to communicate with, storing the address and identity of bots and bot controllers.

	FY 2007	FY 2008	FY 2009
Software Assurance Education and Research	0.000	1.000	0.000

(U) Program Plans:
FY 2008 Plans:
- Conduct research in software assurance education.

	FY 2007	FY 2008	FY 2009
National Repository of Digital Forensic Intelligence	0.000	1.120	0.000

(U) This effort will focus on the goal of the National Repository of Digital Forensic Intelligence.

(U) Program Plans:
FY 2008 Plans:
- Pursue efforts relating to the National Repository of Digital Forensic Intelligence.

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(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Language Translation IT-04	70.539	71.423	75.019	72.433	52.593	52.593	52.593

(U) Mission Description:

(U) This project is developing powerful new technologies for processing foreign languages that will provide critical capabilities for a wide range of military and national security needs, both tactical and strategic. The technologies and systems developed in this project will enable our military to automatically translate and exploit large volumes of speech and text in multiple languages obtained through a variety of means.

(U) Current U.S. military operations involve close contact with a wide range of cultures and peoples. The warfighter on the ground needs hand-held, speech-to-speech translation systems that enable communication with the local population during tactical missions. Thus tactical applications imply the need for two-way (foreign-language-to-English and English-to-foreign-language) translation.

(U) Because foreign-language news broadcasts, web-posted content, and captured foreign-language hard-copy documents can provide insights regarding local and regional events, attitudes and activities, language translation systems also contribute to the development of good strategic intelligence. Such applications require one-way (foreign-language-to-English) translation. Exploitation of the resulting translated content requires the capability to automatically collate, filter, synthesize, summarize, and present relevant information in timely and relevant forms.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Spoken Language Communication and Translation System for Tactical Use*	16.757	14.188	11.533

*Formerly known as Situation Presentation and Interaction.

(U) The Spoken Language Communication and Translation System for Tactical Use (TRANSTAC) program will develop technologies that enable robust spontaneous two-way tactical speech communications between our warfighters and native speakers. The program addresses the issues surrounding the rapid deployment of new languages, especially, low-resource languages and dialects. TRANSTAC is building upon

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existing speech translation platforms to create a rapidly deployable language tool that will meet the military's language translation needs. TRANSTAC is currently focusing on key languages of the Middle East region.

(U) Program Plans:

FY 2007 Accomplishments:

- Performed mission needs analysis and aggressive initial language data collection.
- Demonstrated a proof-of-principle, two-way Iraqi Arabic system free-form exchange between English and Iraqi Arabic speakers in specific domains.
- Provided seventy-five (75) Iraqi Arabic Systems for in-theater experimental fielding.
- Established a Call-A-Translator Service in Iraq for in-field use and rapid data collection.
- Demonstrated prototype two-way Farsi system.

FY 2008 Plans:

- Perform additional mission needs analysis and aggressive language data collection.
- Develop new two-way translation software technologies for insertion into, and enhancement of, the two-way Iraqi systems.
- Develop tools for rapid deployment of new languages and dialects.
- Further enhance recognition and translation performance.
- Develop smaller form-factor prototypes to facilitate mobile use (towards eyes-free, hands-free) translation systems.
- Increase robustness of the prototypes to address the issue of noisy environments.

FY 2009 Plans:

- Update/enhance the experimental systems in the field.
- Continue mission needs analysis and aggressive language data collection.
- Develop two-way translation systems in other languages that will enable the user to not only translate words but also communicate and carry on limited conversation.
- Develop context management translation techniques.

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	FY 2007	FY 2008	FY 2009
Global Autonomous Language Exploitation (GALE)*	50.654	48.935	46.396

*Formerly part of Automated Speech and Text Exploitation in Multiple Languages.

(U) The Global Autonomous Language Exploitation (GALE) program will develop and integrate technology to enable automated transcription and translation of foreign speech and text along with content summarization. Presently, the exploitation of foreign language speech and text is slow and labor intensive. GALE will provide, in an integrated product, automated transcription and translation of foreign speech and text along with content summarization. When applied to foreign language broadcast media and web-posted content, GALE will enhance open-source intelligence and local/regional situational awareness and eliminate the need for translation and subject matter experts at every military site where such information is obtained. Thus, GALE will also reduce the military manpower requirements for translators and mitigate the escalating need for trained support personnel. GALE will tightly integrate multidisciplinary research and produce prototype systems. Earlier DARPA work in foreign language processing yielded an initial integrated architecture concept for speech transcription and text translation, resulting in near edit-worthy text. Continuing work under GALE will produce a fully mature integrated architecture and dramatically improve transcription and translation accuracy by exploiting context and other clues. GALE will address unstructured speech such as talk show conversations and chat room communications and develop timely, succinct reports and alerts for commanders and warfighters.

(U) Program Plans:

FY 2007 Accomplishments:

- Designed and documented a GALE architecture based on the industry standard Unstructured Information Management Architecture (UIMA).
- Created architectural components that combine the output of multiple machine translation engines.
- Identified workflows of all processing engines and provided integration of these workflows on top of the architectural foundation.
- Developed an integrated approach where the problem is viewed mathematically as a single system, with foreign speech/text as input, and English text and distilled information as output.
- Evaluated GALE translation engines on Arabic and Chinese languages for structured and unstructured speech and text.
- Improved translation capabilities, reducing the translation errors by a factor of two in the first year.
- Evaluated summarization technologies.

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– Performed a utility study and evaluated the effectiveness of the end-to-end system relative to a baseline search engine.

FY 2008 Plans:

– Develop methods to optimize the parameters of speech-to-text acoustic models such that transcription errors are minimized on the training data.
– Develop discriminative training algorithms to optimize word alignment and translation quality.
– Implement an integrated search of speech-to-text transcription and machine translation.
– Integrate metadata extraction into the speech-to-text components.
– Evaluate translation and summarization technologies.
– Transition technologies developed by the GALE program into high-impact military systems and intelligence operations centers.
– Incorporate syntax analysis with machine translation algorithms.

FY 2009 Plans:

– Develop methods for porting technology into new languages.
– Perform design and feasibility experiments for extraction-empowered machine translation, where the system extracts the meaningful phrases (e.g., names and descriptions) from foreign language text for highly accurate translation into English.
– Incorporate predicate-argument analysis to enhance machine translation and summarization.
– Complete the architecture for a summarization system that incorporates adaptive filtering, focused summarization, information extraction, contradiction detection, and user modeling.

	FY 2007	FY 2008	FY 2009
Multilingual Automatic Document Classification, Analysis and Translation*	3.128	8.300	12.414

*Formerly part of Automated Speech and Text Exploitation in Multiple Languages.

(U) The Multilingual Automatic Document Classification, Analysis and Translation (MADCAT) program will develop and integrate technology to enable exploitation of captured, foreign language, hard-copy documents. Hard-copy documents, including notebooks, letters, ledgers, annotated maps, newspapers, newsletters, leaflets, pictures of graffiti, and document images (e.g., PDF files, JPEG files, scanned TIFF images, etc.) resident on magnetic and optical media captured in the field may contain important but perishable information of great potential value to the warfighter. These documents often contain machine printed and handwritten text in various combinations and orientations in one or

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more languages. Unfortunately, due to limited human resources and the immature state of applicable technology, our military does not currently have the ability to exploit, in a timely fashion, ideographic and script documents that are either machine printed or handwritten in Arabic or Chinese. The MADCAT program will address this need by producing devices that would enable soldiers to convert such captured documents to readable English in the field. MADCAT will substantially improve the applicable technologies, in particular document analysis and optical character recognition/optical handwriting recognition (OCR/OHR), tightly integrate these with translation technology, and create technology demonstration prototypes for field trials.

(U) Program Plans:

FY 2007 Accomplishments:

- Implemented new methods for Optical Character Recognition using 2-D linear transform techniques and graph theory matching techniques.

FY 2008 Plans:

- Improve methods for document segmentation (e.g., title, address box, columns, lists, embedded picture/diagram/caption, annotation, signature block, etc.).
- Improve script (e.g., Roman vs. Cyrillic) and language (e.g., Farsi vs. Arabic) identification.
- Develop algorithms for document type identification (e.g., letter, ledger, annotated map, newspaper, etc.).
- Develop means to discriminate and separate handwriting from printed regions and improve OCR/OHR technologies.
- Develop the means to interpret different regions within a document, for example, to extract the particulars from an address field or the axes of a table.

FY 2009 Plans:

- Develop algorithms to predict the syntactic structure and propositional content of text.
- Develop tightly integrated technology prototypes that convert captured documents into readable and searchable English.
- Integrate these improvements with the translation and summarization components of GALE.
- Enable efficient metadata-based search and retrieval.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Information and Communications Technology PE 0602303E, Project IT-04

	FY 2007	FY 2008	FY 2009
Robust Automatic Translation of Speech (RATS)	0.000	0.000	4.676

(U) The Robust Automatic Translation of Speech (RATS) program will address noisy and hostile conditions where speech is degraded by distortion, reverberation, and competing conversations. Research into the issue of robustness to enhance the capabilities of speech processing would enable soldiers to hear or read clear English versions of what is being said in their vicinity, despite the noisy environment. RATS technology will build upon advances in GALE technology.

(U) Program Plans:
FY 2009 Plans:
- Improve the robustness of automatic speech transcription and translation algorithms in adverse environments (noise, distortion, reverberation, and competing speech signals).
- Evaluate the relative benefits (performance versus computational requirements) of noise suppression and speech exploitation based on a single microphone versus using multi-microphone arrays.
- Assess the utility of eye-tracking as an adjunct to audio-based source localization.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	165.395	174.680	145.262	135.671	134.372	134.510	128.893
Cognitive Systems Computing Foundations COG-01	13.870	4.474	0.000	0.000	0.000	0.000	0.000
Cognitive Computing COG-02	94.945	94.987	88.392	78.688	79.392	79.530	79.857
Collective Cognitive Systems and Interfaces COG-03	56.580	75.219	56.870	56.983	54.980	54.980	49.036

(U) Mission Description:

(U) The Cognitive Computing Systems program element is budgeted in the Applied Research budget activity because it is developing the next revolution in computing and information processing technology that will enable computational systems to have reasoning and learning capabilities and levels of autonomy far beyond those of today's systems. The ability to reason, learn and adapt will raise computing to new levels of capability and powerful new applications.

(U) Military command, control, communications, and intelligence/information systems must support warfighters in 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 with the capability to orchestrate high-tempo planning, rehearsal, and execution. The programs in this project are developing and testing innovative, secure architectures and tools to enhance information processing, dissemination, and presentation capabilities. The programs provide the commander insight into the disposition of enemy and friendly forces, a joint situational awareness picture that will improve planning, decision-making, and execution support capability, as well as secure multimedia information interfaces and software assurance to the warfighter "on the move." Integration of collection management, planning, and battlefield awareness are essential elements for achieving battlefield dominance through assured information systems.

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

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(U) The Collective Cognitive Systems and Interfaces Project will dramatically improve warfighter and commander effectiveness and productivity using advanced cognitive approaches that enable faster, better informed, and more highly coordinated actions than those of our enemies. This will be accomplished by developing revolutionary methods that increase our information processing capabilities, enhance our situational awareness, and enable more cohesive group action by our forces. Critical technical areas addressed in this project include automated coordinated decision support, information sharing, and ensured communications.

(U) **Program Change Summary:** *(In Millions)*	**FY 2007**	**FY 2008**	**FY 2009**
Previous President's Budget	180.003	179.728	202.439
Current Budget	165.395	174.680	145.262
Total Adjustments	-14.608	-5.048	-57.177
Congressional program reductions	-10.000	-5.048	
Congressional increases	0.000		
Reprogrammings	0.000		
SBIR/STTR transfer	-4.608		

(U) Change Summary Explanation:

FY 2007	The decrease reflects the SBIR/STTR transfer and a $10 million decrease to the Architectures for Cognitive Information Processing program for the Section 8043 rescission.
FY 2008	The decrease reflects Congressional program reductions to Robust Robotics, Integrated Learning, and a reduction for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions.
FY 2009	The decrease reflects transfer of maturing cognitive technologies from the Personalized Assistant that Learns (PAL) program to Budget Activity 3 for transition opportunities in command and control systems and reduced funding for collaborative cognition programs as they prepare for transition.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Cognitive Computing Systems PE 0602304E, Project COG-01

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Cognitive Systems Computing Foundations COG-01	13.870	4.474	0.000	0.000	0.000	0.000	0.000

(U) Mission Description:

(U) The Cognitive Systems Computing Foundations project seeks to make fundamental scientific improvements in our understanding of and ability to create more intelligent information and computing systems such as developing the necessary foundational hardware architectures and software methods to facilitate learning and inference capabilities that are crucial to intelligent computing. These new computing foundations will help us move far beyond today's standard Von Neumann computing model. Transition goals include next-generation network-centric systems and platform-specific information collection and processing systems. This project will complete with FY 2008 funding and on-going efforts will continue in other Program Elements.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Self-Regenerative Systems (SRS)	12.770	4.474	0.000

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

(U) SRS-enabled systems will be able to reconstitute their full functional and performance capabilities after experiencing an accidental component failure, software error, or even an intentional cyber-attack. SRS systems will show a positive trend in reliability, exceed initial

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operating capability and approach a theoretical optimal performance level over long time intervals. They will also maintain robustness and trustworthiness attributes even with growth and evolution in functionality and performance. The program will explore a self-regenerative operating system that will automatically recover after failure or attack on its configuration files, underlying devices or applications; and provide core survivability functionality, programming interfaces and system services that support rapid prototyping, construction, and deployment of survivable applications.

(U) Program Plans:
FY 2007 Accomplishments:
- Developed technologies to expand capabilities to diagnose and assess damage, and repair and recover from damage caused by accidental faults or malicious activities.

FY 2008 Plans:
- Develop additional general strategies to automatically immunize systems against new attacks and preempt insider attacks; combining and correlating information from system layers using direct user challenges.

	FY 2007	FY 2008	FY 2009
Secure Open Systems Institute for Defense (SOSI)	1.100	0.000	0.000

(U) Program Plans:
FY 2007 Accomplishments:
- Initiated research on Secure Open Systems.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research			R-1 ITEM NOMENCLATURE Cognitive Computing Systems PE 0602304E, Project COG-02				
COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Cognitive Computing COG-02	94.945	94.987	88.392	78.688	79.392	79.530	79.857

(U) Mission Description:

(U) The Cognitive Computing project will develop core technologies that enable computing systems to learn, reason and apply knowledge gained through experience, and to respond intelligently to new and unforeseen events. These technologies will lead to systems with increased self reliance, cooperative behavior, the capacity to reconfigure themselves, and survivability with reduced programmer intervention. In the real-time environment of military operations, cognitive networks and systems that can learn, reason, draw on their experience, automatically adapt to maintain critical functionality, effectively assist their military user and improve their responses over time will be crucial to operational success. These capabilities will make the difference between mission success and mission degradation or failure, even in the event of cyber-attack or component attrition resulting from kinetic warfare or accidental faults and errors. Systems that learn and reason will reduce the requirement for skilled system administrators and dramatically reduce the overall cost of system maintenance. As the military moves towards a dynamic expeditionary force, it is critical for systems to become more self sufficient. Overall, the project will extend fundamental computing capabilities to deal with real-world information complexity and uncertainty.

(U) The machine learning, reasoning, and human-machine dialogue techniques developed in this project, in particular, the Personalized Assistant that Learns program, have great applicability to command and control systems and are budgeted to begin transition to battlefield systems in FY 2008/2009. Candidate systems include the Strategic Command (STRATCOM) Global Strike Operations Center Strategic Knowledge Info Web (SKIWeb), the Army's Command Post of the Future (CPOF), the Navy's Composeable FORCENet (CFn), Navy Marine Corp Intranet (NMCI) and the Air Force's Air Tasking Order (ATO) programs. Additional details are provided under PE 0603760E, Project CCC-01.

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(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Personalized Assistant that Learns (PAL)*	39.164	34.114	27.344

*Previously this was part of Integrated Cognitive Systems.

(U) The Personalized Assistant that Learns (PAL) program seeks to enable intelligence in information processing systems so that critical DoD systems can better support, not burden, the warfighter. Due to DoD/military reductions in manpower levels, and in spite of the integration of advanced information technologies and automation throughout defense systems, the workload on the warfighter steadily increases. Modern computing systems, though powerful, are woefully lacking in the capability to self-configure, adapt, and learn. They lack even rudimentary intelligence. This deficiency places a heavy burden on the warfighter to operate and maintain the very information technology on which modern warfare depends. The PAL program will develop advanced technology to enable a new class of cognitive systems capable of assisting military commanders and decision makers. PAL will build upon prior DARPA programs that developed improved human-computer interaction capabilities and highly-responsive computing systems. PAL systems will be able to plan ahead and understand the world well enough to plausibly anticipate future events. Most importantly, PAL systems will have embedded learning capabilities that will allow them to retain prior learned knowledge, apply this knowledge to new scenarios and ultimately provide faster and more effective assistance. Overall, the ability to learn will enable the performance of a PAL system to improve over time. Cognitive systems technologies developed in this program will be applied and demonstrated in the Increased Command and Control Effectiveness (ICE) program (PE 0603760E, Project CCC-01) prior to transition into Command Operations.

(U) The PAL program is creating a revolutionary technology for commanders and warfighters - the first comprehensive system that will dramatically empower commanders to understand at a glance all aspects of the current military situation, radically reduce manpower and labor required in command posts and in the field, and automate the massive number of administrative and analytical tasks characteristic of today's command centers. PAL is creating a new generation of machine learning technology that will enable information systems to automatically adjust to new environments and new users, helping commanders adapt to new enemy tactics, evolving situations and priorities, accelerating the incorporation of new personnel into command operations, and making more effective, focused use of resources. Applications developed in PAL will be adapted and hardened in order to be integrated into existing military systems. Future capabilities to be inserted will result in the ability to

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turn diverse, multi-source data into actionable information for commanders and warfighters; dramatic manpower reductions; corporate memory retention of both the larger conflict history and the history of each specific command center; and intelligent information presentation.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed, evaluated, and demonstrated the first instance of an intelligent cognitive assistant capable of learning the user's activities, topics of interest, expertise, information needs, priorities and organizational roles.
- Developed, evaluated, and demonstrated the use of learned knowledge by the cognitive system to (1) prepare information products such as briefings, (2) organize and prioritize emails, files, and documents, and (3) quickly find additional relevant information.
- Developed, demonstrated, and refined core machine learning, knowledge base and flexible planning technologies to enable development of a cognitive planning agent capable of recognizing what tasks the user is performing and how the user is performing them.
- Developed, evaluated, and demonstrated the use of learned planning knowledge by the planning agent to (1) provide suggestions, and additional information, (2) perform tasks automatically, and (3) delegate tasks to others and monitor their execution.
- Successfully demonstrated PAL technology on real-world data from the STRATCOM SKIWeb system.

FY 2008 Plans:

- Develop, demonstrate, and evaluate core physical awareness, cyber-awareness, multimodal dialogue, machine learning, and representation and reasoning technologies to support cognitive assistant executive functions.
- Formulate an approach for receiving user guidance and translating it into the precise machine language necessary for both implementation and verification of user purpose and intent.
- Demonstrate the utility of PAL technologies for the Army Knowledge Online's Company Commander.com.
- Optimize PAL technology to provide maximum benefit to STRATCOM SKIweb users.
- Demonstrate PAL technologies on data from the Army's Command Post of the Future (CPOF), Navy Marine Corp Intranet (NMCI) and the DoD-wide Web Timeline Analysis System (WebTAS). Use the results of these demonstrations as lessons-learned for integration activities being conducted in military environments including the CPOF, the CFn, NMCI, and the ATO Programs. (See PE 0603760E, Project CCC-01 for additional details).

FY 2009 Plans:

- Develop a dialogue system with general and domain-specific semantics for eliciting natural language advice from the warfighter and other end users of PAL technology and PAL-enhanced systems.

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- Develop the ability for an integrated cognitive system such as PAL to examine its own behavior and learn from that experience.
- Based on initial user feedback, extend, improve, and optimize PAL technology for implementation and operational use in STRATCOM's SKIweb, the Army's Command Post of the Future (CPOF), Navy Marine Corp Intranet (NMCI), and the DoD-wide Web Timeline Analysis System (WebTAS) Programs.

	FY 2007	FY 2008	FY 2009
Integrated Learning*	15.740	20.011	17.160

*Previously this was part of Foundational Learning Technology.

(U) The Integrated Learning program is creating a new computer learning paradigm in which systems learn complex workflows from warfighters while the warfighters perform their regular duties. Current machine learning technologies cannot learn these complex workflows. The effort is focused on military planning tasks such as air operations center (AOC) planning and military medical logistics. With this learning technology, it will be possible to create many different types of military decision support systems that learn by watching experts rather than relying on hand-encoded knowledge (which is expensive and error prone to produce). The new learning paradigm differs from conventional machine learning in that it does not rely on large amounts of carefully crafted training data. Rather, in the new paradigm the learner works to "figure things out" by combining many different types of learning, reasoning, and knowledge. For instance, to learn AOC tasks, the computer learner combines what it observed the warfighters doing with the knowledge it has about aircraft, and reasons about airspace de-confliction to create a generalized model that can then be used to perform the entire AOC task, or provide intelligent instruction to other warfighters performing the same task. Such a cognitive system will ultimately need the capability to build and update its own internal model of the world and the objects in it without human input.

(U) Program Plans:

FY 2007 Accomplishments:

- Successfully formulated learning as an integrated problem solving process and developed representation languages that enable different components, e.g., planning, reasoning, simulation, etc., to share information during the learning process.
- Constructed integrated systems that can learn air control order planning and military medical evacuation planning by being shown a single demonstration by a human expert.
- Evaluated systems via a competition of their learning performance against that of human novices.

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FY 2008 Plans:
- Enhance integrated learning systems so the systems form explicit learning goals, make plans to achieve these goals, create hypotheses about learned knowledge where appropriate, and resolve sources of uncertainty in learned knowledge where it exists.
- Expand systems so they combine different types of knowledge and reasoning, based on the situation and information that is available.
- Modify existing algorithms so they emit and track uncertainty about information.
- Evaluate systems by having them learn expanded/full air control order (ACO) planning processes and procedures and military medical evacuation planning.

FY 2009 Plans:
- Modify the integrated learning systems so they can incorporate new software components dynamically and utilize the new capabilities while learning.
- Create control algorithms for the systems that manage credit-and-blame assignment on a component-by-component basis so that if conflicts arise the system can reason about which piece of conflicting information is more likely to be accurate.
- Create control algorithms that reason about the costs/benefits of resolving a particular conflict and direct system performance accordingly.
- Expand the scope of the problems being learned so the systems learn full air tasking order (ATO) planning processes and full military medical logistics planning.
- Evaluate systems by having them compete against novice humans.
- Enable cognitive systems to learn and manipulate their own models and concepts.

	FY 2007	FY 2008	FY 2009
Bootstrapped Learning*	5.266	6.673	9.081

*Previously this was part of Knowledge Representation and Reasoning.

(U) The Bootstrapped Learning program will provide computers with the capability to learn complex concepts the same way that people do, from a customized curriculum designed to teach a hierarchy of concepts at increasing levels of complexity, where learning each new level depends on having successfully learned the previous level. Such a capability is envisioned as revolutionary for cognitive systems in that bootstrapped learning systems will be "reprogrammable" in the field using the same modes of natural instruction used to train people, and without the need for

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software developers to modify the software code. In Bootstrapped Learning, at each level, a rich set of knowledge sources (such as training manuals, examples, expert behaviors, simulators, and references and specifications that are typically used by people learning to perform complex tasks) will be combined and used to generate concepts and a similar set of knowledge sources for the next level. This will enable rapid learning of complex high-level concepts, a capability that is essential for autonomous military systems that will need to understand not only what to do but, ultimately, why they are doing it, and when what they are doing may no longer be appropriate. To be useful, a military system must not only carry out the specific task/mission for which it is programmed but also be able to reflect on its own ability to do so, and do this in the context of its operator/controller's intent.

(U) Program Plans:

FY 2007 Accomplishments:

- Created a general purpose "Ladder Interface" used to decouple the bootstrapped learning system from the problem domains and instructional materials provided to them.
- Developed a pair of components that together implement both sides of the ladder interface and will serve as development aids.

FY 2008 Plans:

- Produce an initial prototype end-to-end system capable of bootstrapped learning, integrating different types of learning, input modalities, and repeatedly building on prior learning.
- Develop a complete electronic curriculum for three domains, including prerequisite knowledge, teaching algorithms, as well as curriculum development tools.
- Demonstrate a specific ability to learn a curriculum composed of at least three related lessons via at least three different interaction modalities and at least two different learning processes.

FY 2009 Plans:

- Demonstrate a single system capable of being instructed to perform in three diverse domains.
- Demonstrate the ability of a system to repeatedly acquire new knowledge that drives future learning and cumulatively adds to the system's knowledge.
- Validate that configuration and control of critical, autonomous military hardware can be addressed with bootstrapped learning technology.

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	FY 2007	FY 2008	FY 2009
Knowledge Representation and Reasoning Technology	1.147	2.346	7.807

(U) The Knowledge Representation and Reasoning Technology program will develop enabling technologies to acquire, integrate, and use high performance reasoning strategies in knowledge-rich domains. Such technologies will provide DoD decision makers with rapid, relevant knowledge from a broad spectrum of sources that may be dynamic and/or inconsistent. Significant reasoning challenges arise from the fact that critical knowledge involves context, temporal information, complex belief structures, and uncertainty. To address these challenges new capabilities are needed to extract key information and metadata, and to exploit these via context-capable search and inference (both deductive and inductive). DoD systems sense, capture, and store information in the form of text, audio, imagery, and video. Therefore, advanced machine reasoning capabilities must extract knowledge from and reason about all types of multimedia data. Visual-spatial reasoning, which is perhaps the most powerful form of human reasoning, yet the one least covered by machine cognition, is of special interest. This research will explore new computational models to enable command and control systems to use conceptual representations to perform visual-spatial reasoning and to assist the commander in understanding and analyzing complex battlefield scenarios.

(U) The cost of handcrafting information within the narrow confines of first order logic or other artificial intelligence (AI) formalisms is prohibitive for many applications. Machine reading addresses these issues by replacing the expert (and associated knowledge engineer) with un-supervised or self-supervised learning systems, systems that "read" natural text and insert it into AI knowledge bases, i.e. data stores especially encoded to support subsequent machine reasoning. Machine reading requires the integration of multiple technologies. Natural language processing must be used to transform the text into candidate internal representations. Knowledge representation and reasoning techniques must be used to test this new information, and determine how it is to be integrated into the system's evolving models so that it can be used for effective problem solving. While tremendous strides have been made in individual research areas, few efforts have attempted to integrate them to achieve machine reading.

(U) Program Plans:

FY 2007 Accomplishments:

– Developed the initial integrated knowledge representation and learning technology that enables effective representation of essential forms of knowledge.

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FY 2008 Plans:
- Explore novel methods for acquiring new knowledge including direct input through processing natural language text**.**
- Perform a proof-of-concept of learning-by-reading by the machine reading of small focused texts with the goal of encoding and querying at narrow but deep semantic levels.

FY 2009 Plans:
- Demonstrate the ability of a single system to acquire and organize information directly from unstructured narrative text in multiple domains.
- Extend knowledge representation to support machine reading of large (e.g. open source web) amounts of material with the goal of encoding and querying at broad but shallow semantic levels.
- Create a targeted reading capability to resolve conflicts and fill gaps in existing knowledge models.
- Develop a general inference engine based on spatial representations, transformations, and reasoning techniques, in order to provide a more intuitive, common sense, human-like and efficient visual reasoner.
- Create learning mechanisms for the discovery of novel object categories and then design, develop, and demonstrate an artificial system that is capable of context-sensitive visual scene interpretation and understanding.

	FY 2007	FY 2008	FY 2009
Foundational Learning Technology	17.317	14.603	12.000

(U) The Foundational Learning Technology program 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 and existing information stores. Foundational Learning technologies have broad applicability to cognitive systems, and will result in military systems that are more robust, self-sufficient, and require minimal or no platform-specific customization. Current efforts will develop hybrid learning techniques to create cognitive systems capable of learning military strategy, leveraging large amounts of prior knowledge, incorporating external guidance and applying prior knowledge in real-time to the naturally changing environment, all without programmer intervention. This includes the integration and application of advanced machine learning techniques to further enable cognitive computing systems to learn from experience and adapt to changing situations. A very promising approach involves transfer learning techniques that transfer knowledge and skills learned for specific situations to novel, unanticipated situations and perform appropriately and effectively the first time a novel situation is encountered. This is essential because most military

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operations occur in ever-changing environments and U.S. forces and systems must be able to act appropriately and effectively the first time each novel situation is encountered.

(U) Recent advances in neuroscience suggest that much of the rich and varied structure of the neo-cortex may be the natural consequence of a relatively simple cortical algorithm adapting itself to the structure latent in the input it receives from the world. It is therefore plausible to seek advances by modeling the sub-symbolic "instruction set" of the brain. Success here would provide alternatives to the symbolic approaches that currently predominate in areas such as perception, reasoning, and language.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated the ability of a cognitive agent to learn large amounts of knowledge for performance in a specified domain on an unknown task within the same domain.
- Designed and developed hybrid learning systems that allow cognitive systems to generalize based on information gathered; and learn to operate successfully in similar, but not identical situations, adapt to a wide variety of naturally-occurring situations, and perform better over time.

FY 2008 Plans:

- Demonstrate the ability of a cognitive agent to learn, combine, and restructure knowledge in multiple domains and apply this to solve novel problems in those domains.
- Demonstrate the ability of a cognitive agent to generalize knowledge from particular domains and discover how to apply it to a problem in a new domain.
- Demonstrate the ability of a cognitive agent to synthesize knowledge and skills acquired from multiple domains, apply them effectively to problems in new domains, and demonstrate the ability to propose novel problem solution methods when specified resources are unavailable.

FY 2009 Plans:

- Conceptualize and propose algorithms that can take unorganized numeric inputs and, through interaction, "see" that these inputs represent some structured universe that obeys structured laws.
- Construct a single, massively parallel, general-purpose algorithm which could start with zero knowledge of its environment, and then grow to represent the structure latent in that environment.

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	FY 2007	FY 2008	FY 2009
Robust Robotics*	16.311	17.240	15.000

*Formerly Learning Locomotion and Navigation.

(U) The Robust Robotics program will develop advanced robotic technologies that will enable autonomous (unmanned) mobile platforms to perceive, understand, and model their environment; navigate through complex, irregular, and hazardous terrain; make intelligent decisions corresponding to previously programmed goals; and interact cooperatively with other autonomous and manned vehicles. These capabilities will enable robotic vehicles to support warfighters in a variety of situations and terrains, including transportation, logistics, reconnaissance, and active battle. A key objective is robust navigation and locomotion, since this underlies the ability to move through the difficult and unpredictable terrain of theater operations, which may include highly irregular and mountainous areas, partially-destroyed roads, rubble-filled urban terrain, and other vehicles and personnel. This program also supports the DARPA Urban Challenge.

(U) Within the program area, efforts are being made to develop learning and reasoning technologies to address specific concerns in both wheeled and legged robotic systems. Current systems for autonomous ground robot navigation typically rely on hand-crafted, hand-tuned algorithms. While these systems may work well in open terrain or on roads with no traffic, performance falls far short in obstacle-rich and highly-irregular environments. In contrast, the approach taken here is to develop systems that automatically learn to interpret sensor data and apply this knowledge to actuator control to improve locomotion and navigation in complex environments. Learning techniques will include (but not be limited to) reinforcement learning and learning from examples. These advancements will open new horizons for unmanned military operations, surveillance and reconnaissance, and dramatically advance the capabilities of autonomous vehicles. Tasks requiring higher-level computation, such as perception-based navigation and a high degree of freedom articulation will greatly benefit as well.

(U) Although current approaches to autonomous navigation of unmanned vehicles have achieved notable success in recent years, they suffer from limitations, having been developed for static environments and not for dynamic real-world environments. Examples of the challenges posed by a complex dynamic real-world environment include: (1) robotic vision outdoors, under windy conditions that result in the movement of vegetation, trees, and leaves and, when a body of water is present, waves; and (2) path-planning in the presence of moving “obstacles” such as people and other (manned or unmanned) vehicles. Improvements in robotic vision and scene understanding, including the capability to predict the future location and even the intent of moving objects, need to be integrated with more sophisticated approaches to path planning. This would set the stage for autonomous interacting robots that share information and collaborate in performing tasks. For example, interacting robots could

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collaborate in planning/traversing a diversity of routes and thereby enhance their likelihood of quickly finding a viable and/or (nearly) optimal path.

(U) Program Plans:

FY 2007 Accomplishments:

- Explored various learning technologies that enabled rapid adaptation by robots to new physical environments and improved autonomous vehicle speed over rough terrain.
- Developed several learning methods that allowed learned navigation algorithms to surpass the performance of a baseline system which was demonstrated through several experiments.
- Explored "learning from example" and "reinforcement learning" applications to develop technology for autonomous vehicle systems to learn and gather experience without relying on a programmer to anticipate all eventualities. These learning approaches were evaluated through a series of tests in varying terrains.
- Funded technology development contracts and program planning support for the DARPA Urban Challenge.

FY 2008 Plans:

- Create new learning algorithms that use dynamic gaits to enable legged laboratory robots (that are small scale versions of operational sized platforms) to run over uneven terrain.
- Evaluate the new learning algorithms on a series of different terrain settings in a competitive fashion.
- Transfer the best performing navigation methods learned on a small-scale vehicle to the large robotic vehicle, Crusher, to operate at increased speeds in complex environments.
- Fund prizes and support for the DARPA Urban Challenge.

FY 2009 Plans:

- Create new and modify existing learning algorithms to enable legged laboratory robots (that are small scale versions of operational sized platforms) to run over terrain at speeds proportional to humans.
- Evaluate the new learning algorithms on a series of different terrain settings in a competitive fashion.
- Port learning locomotion algorithms to larger scale vehicles to increase mobility of larger scale robots.
- Create learning locomotion toolkits that will control a diverse set of high degree-of-freedom vehicles on rough terrain.

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

(U) Other Program Funding Summary Cost:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research			R-1 ITEM NOMENCLATURE Cognitive Computing Systems PE 0602304E, Project COG-03				
COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Collective Cognitive Systems and Interfaces COG-03	56.580	75.219	56.870	56.983	54.980	54.980	49.036

(U) Mission Description:

(U) Warfighting is not an individual activity. Battles, engagements, and even peace keeping missions are won by teams of warfighters working in concert with each other and the automated systems that support them. These warfighters are operating in hard settings where action, information, and decision making are distributed and the situation is constantly changing. In these settings, communications, information sharing, and tools that support warfighter coordination are critical.

(U) The Collective Cognitive Systems and Interfaces Project will dramatically improve warfighter and commander effectiveness and productivity using advanced cognitive approaches that enable faster, better informed, and more highly coordinated actions than those of our enemies. This will be accomplished by developing revolutionary methods that increase our information processing capabilities, enhance our situational awareness, and enable more cohesive group action by our forces. Critical technical areas addressed in this project include automated coordinated decision support, information sharing, and ensured communications. Cognitive decision support tools reason about tasks, timings, and interactions so that when plans change or the enemy does not respond as anticipated, U.S. forces can quickly adapt. The quality of such decisions and the effectiveness of our actions depend critically on our ability to take full advantage of all available information in a rapid and flexible manner. This requires the capability to share information and to automatically integrate distributed information bases for broad tactical battlespace awareness. Finally, team cohesion requires effective and reliable communication in difficult environments such as an urban setting where radio signal propagation is complex. Here the approach is to develop cognitive communications management and control algorithms that reason about channel conditions, higher-level application connectivity requirements and related factors, and decide (often as a group) what parameters (e.g., frequency) each radio will use. The suite of programs under this project will significantly advance the military's ability to address and deal with complex situations in operational environments.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Cognitive Computing Systems PE 0602304E, Project COG-03

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Collaborative Cognition	27.710	28.800	17.000

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

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

- A key lesson learned from Operation Iraqi Freedom (OIF) is the importance of accurate observational reporting by ground soldiers. The Advanced Soldier Sensor Information System and Technology (ASSIST) effort will develop an integrated information system that exploits soldier-worn sensors to augment the soldier's ability to capture, report, and share information in the field. Communication of timely and accurate information is vital for enhanced situational understanding and overall operational effectiveness in urban combat and post-conflict stability operations. While a range of standardized reporting mechanisms are in use today, the confusion of the

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battlefield/urban operations combined with physical and psychological stresses on the warfighters can make the task of reporting very difficult. Furthermore, existing verbal and text-format reports limit the soldier's ability to capture and convey the full picture, particularly annotated visual information. The ASSIST effort will develop an integrated system using advanced technologies for processing, digitizing and analyzing information captured and collected by soldier-worn sensors. It will draw heavily on the experiences and lessons learned from previous OIF missions and other surveillance and reconnaissance missions. A baseline system will demonstrate the capture of video/still images together with voice annotations and location-stamping. The advanced system will demonstrate automatic identification and extraction of key objects, events, activities and scenes from soldier-collected data. The system will create knowledge representations that will serve as an input to an array of warfighter products including augmented maps, situational analysis tools, and query and answer capabilities.

(U) Program Plans:

– Coordination Decision-Support Assistants (COORDINATORs)

FY 2007 Accomplishments:

-- Developed distributed coordination technology that reasons about making changes to task timings, assignments, and selection from pre-planned contingencies.
-- Tested coordination algorithms in a lab setting on large-scale coordination problems (100 COORDINATORs, 10,000 mission tasks), and demonstrated that algorithms achieve nearly optimal results in seconds.
-- Developed a meta-cognition technology that reasons about resource allocation (i.e., where a given COORDINATOR should spend its processing time), so the entire system can engage in difficult processing tasks but still respond in real time.
-- Developed a Commander's COORDINATOR that can selectively "drill down" into portions of the mission structure and collect up-to-the-minute information, enabling a commander to make adjustments or recommendations.

FY 2008 Plans:

-- Modify coordination algorithms so they can reason about the physical geolocation of units and coordinate changes in unit location.
-- Modify coordination algorithms so they can operate effectively in network situations where latency may impact communications as it does in field settings.
-- Develop a coordination autonomy controller that enables a COORDINATOR system to interact intelligently with its human user, generating desired options and waiting for appropriate periods of time for the human to respond.
-- Develop a change evaluation module that couples the COORDINATOR technology to GPS units so the system automatically knows the location of a given unit.

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-- Develop a basic representation for military decision making policies and procedures so the COORDINATORs follow said procedures, and decisions are made at the proper levels.
-- Evaluate COORDINATORs technologies in a field setting.

FY 2009 Plans:
-- Develop a full and general purpose representation for military decision making policies and procedures so the COORDINATORs know when information must be propagated, and to whom, and reason about the full spectrum of decision authority.
-- Add learning algorithms to the change evaluation module so it can learn to anticipate problems before they arise.
-- Add resources and models of resources to the plan representation language and modify the coordination algorithms to coordinate over resources, (e.g., troop transportation vehicles).
-- Integrate COORDINATORs technologies with SOFTools, a planning system used by U.S. Special Operations Command.
-- Continue evaluating COORDINATORs in a field setting.

– Advanced Soldier Sensor Information System and Technology (ASSIST)

FY 2007 Accomplishments:
-- Demonstrated the baseline capture and retrieval system prototype and evaluated the effectiveness of the integrated system in Military Operations on Urban Terrain (MOUT) field exercises.
-- Developed algorithms to identify objects, events, and activities in captured data and to assign correct labels.
-- Exploited multimodal sensor streams and contextual information.
-- Created a taxonomy of objects and events, collected test data, and developed procedures and metrics for advanced technology evaluation.
-- Developed a laptop-based user search and visualization interface for accessing logged information captured by multiple soldiers.
-- Demonstrated temporal event representation and outdoor spatial representation.
-- Deployed a research prototype to Iraq.
-- Incorporated lessons-learned from the experimental fielding to improve product for the warfighter.

FY 2008 Plans:
-- Demonstrate an automated, sensor-cued collection system for ground patrols.
-- Develop a software system to interpret and automatically index soldier-centric activities, events, scenes, and objects.
-- Develop analysis tools for the collected data.
-- Prototype a two-way capability for alerting patrols in the field.

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FY 2009 Plans:

-- Demonstrate real-time reporting using on-soldier sensors and an intuitive information push/pull user interface.
-- Address the technical challenges associated with providing ASSIST as a real-time capability for the dismounted soldier in the field.
-- Develop and demonstrate a real-time variant for use by dismounted soldiers, with enhancements that include video feeds from airborne platforms.
-- Develop key technological components that enable in-field data sharing and retrieval on a wearable computing/sensor platform.
-- Demonstrate eyes-free, hands-free, attention-free collection of key events and experiences for reporting.
-- Demonstrate tools for analyzing blue-force and red-force trends and patterns.
-- Demonstrate the system's ability to improve its event and object classification performance through learning; demonstrate an accelerated capability for recognizing new classes of events, objects and activities.
-- Integrate advanced multimodal sensor event and object extraction techniques into advanced systems and evaluate the enhanced capabilities.

	FY 2007	FY 2008	FY 2009
Cognitive Networking	20.523	30.986	25.263

(U) The Cognitive Networking research program will develop technologies that provide information systems and communication networks with the ability to maintain their own functionality, reliability and survivability. These technologies will allow the military to focus its critical manpower resources on the mission rather than on the maintenance of its information systems and network infrastructure. Research in this area will create a radical new design for distributed computers, device networks, and the software to manage these systems. Cognitive information processing will be used to optimize networked communications based on current conditions, past experience and high-level user guidance. The Cognitive Networking program comprises three efforts: Situation-Aware Protocols in Edge Network Technologies, Local Area Network droid, and Brood of Spectrum Supremacy.

- The Situation-Aware Protocols in Edge Network Technologies (SAPIENT) effort will develop a new generation of cognitive protocol architectures to replace conventional protocols that fare poorly in extreme network conditions and do not provide adequate service for key applications. Technology developed in the SAPIENT effort will have military utility wherever tactical communications are deployed.

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SAPIENT architectures will represent awareness with a knowledge base that is updated based on specification and observation. This technology enables the automatic adaptation of protocols to the operational environment. SAPIENT will exploit attributes of human cognition, such as learning and self-improvement, and apply them to the automated construction of network protocols. Key research challenges for the SAPIENT effort are the use of these cognitive attributes to dramatically reduce the effect of network impairments on applications while demonstrating a positive trend in this capability as new situations are encountered and learned. Desired capabilities include interoperable knowledge representations and rapid incorporation of new knowledge about applications, network conditions and building blocks from which new protocols can be constructed**.**

- The Local Area Network droid (LANdroid) effort will give warfighters reliable communications in urban settings. LANdroid will accomplish this by creating robotic radio relay nodes that move autonomously to configure and maintain a communications mesh by reasoning about their positions relative to one another and relative to the warfighters. LANdroids will also move as the warfighters move – keeping them covered with communications throughout their operations. LANdroids will be pocket-sized so warfighters can carry several and drop or deploy them as they move through a given area. The effort is creating both the intelligent radio control software and the small radio platforms on which it runs. The technologies will be tested in a physical setting (i.e., not simulated) and at an operationally relevant scale.

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

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(U) Program Plans:

– Situation-Aware Protocols in Edge Network Technologies (SAPIENT)

FY 2007 Accomplishments:

-- Created knowledge representations appropriate for describing some situations encountered in tactical military networks (e.g., weak signals, propagation obstructions, message priorities and security requirements) and for enabling machine response to these situations.
-- Demonstrated SAPIENT capabilities in laboratory venues.
-- Evaluated the impact of mobility on communications.

FY 2008 Plans:

-- Integrate and enhance prototypes and evaluate their performance.
-- Refine new knowledge representations appropriate for describing multiple link situations encountered in tactical military networks and for enabling machine response to these situations including automated learning of effective responses.
-- Refine protocol selection and composition strategies with an integrated learning capability.
-- Demonstrate SAPIENT capabilities in laboratory and experimental airborne venues.

FY 2009 Plans:

-- Integrate and enhance prototypes and evaluate their performance.
-- Implement a functional cognitive learning system that facilitates real-time selection and composition of protocols.
-- Demonstrate an adaptive cognitive prototype in an urban environment using mobile, airborne, and stationary nodes.

– Local Area Network droid (LANdroid)

FY 2008 Plans:

-- Develop control algorithms for LANdroids so they can self-configure (forming the initial network), self-optimize (making small movements to improve the network), and self-heal (move to cover gaps in the network caused by nodes being destroyed or powering down).
-- Develop small robotic LANdroid platforms that meet basic requirements for size and capability.
-- Evaluate a 10-node LANdroid network.

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FY 2009 Plans:
-- Develop control algorithms for LANdroids that enable them to tether the network to warfighters so the network moves as the warfighters move.
-- Develop intelligent power management algorithms for LANdroids so they make intelligent decisions about whether or not to move based on current conditions and expected power expenditures (by moving) and savings (by being in a better location).
-- Develop network load balancing protocols for LANdroids that dovetail with the power management algorithms to enable the network to last as long as possible.
-- Harden the LANdroid robotic platform and reduce its weight.
-- Evaluate algorithms using a 15-node LANdroid network that spans two floors of an indoor building.

– Brood of Spectrum Supremacy (BOSS)
FY 2007 Accomplishments:
-- Developed theoretical analyses of the software-defined radio trade space to assess the distributed aggregation of capabilities over different numbers of moving elements, elements with varying capabilities (e.g., RF and processing), and with different distances and locations.
-- Validated algorithms for network understanding tasks.
FY 2008 Plans:
-- Refine capabilities of Software Communications Architecture (SCA)-compliant platforms, while working within the software-defined radio trade space.
-- Validate implementations for network understanding tasks using SCA-compliant platforms.
FY 2009 Plans:
-- Implement BOSS capabilities on handheld/wearable software-defined radio platforms.
-- Test and evaluate BOSS handheld radios in “real-world” scenarios.

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	FY 2007	FY 2008	FY 2009
Integrated Collective Systems	7.200	15.433	14.607

(U) The Integrated Collective Systems technology program addresses information integration, one of the most critical and challenging problems facing the DoD and continually tops the list of critical defense needs. The current inability to share and integrate data and information results in a fragmented picture of the battlespace where only a fraction of the available information is actually used. The problem has been raised by numerous DoD and service studies as well as by Combatant Commanders themselves. The Integrated Collective Systems program will enable warfighters to take full advantage of all available pertinent information in a rapid and flexible manner. It will create software technologies that enable future warfighters to share information and to automatically integrate distributed information bases for broad tactical battlespace awareness. Ultimately, the selection, generation, sharing, integration and display of information will be handled by cognitive software systems coupled with each warfighter, and as information is shared the network of individual systems will form a collective. Integration of multimedia (text, video, digital photographs) is of particular interest as it may contain valuable intelligence "tidbits" with different degrees of subtlety that can be extremely time-consuming to manually analyze (this is the case today). Once analyzed, such data needs to be indexed and stored so it can be queried and retrieved. Automatic analysis, querying and correlation algorithms need to be developed to minimize manual intervention. The Integrated Collective Systems program consists of two efforts: Digital Network Archive (DNA) and Data Integration and Exploitation SystEm that Learns (DIESEL).

- Current practices in the area of digital storage and information management generally optimize file storage and retrieval for the individual but are poorly suited to the sharing of large volumes of digital information across workgroups and enterprises. The Digital Network Archive (DNA) effort is pursuing a network-based approach to information storage and management that will enable a network-based repository to hold all digital information. Because it resides on the network, the DNA repository will provide a mechanism for the virtual (i.e., logical, not physical) centralization of all enterprise information. DNA technology will enable and facilitate controlled access to information by approved and authenticated users across administrative domains, and in this fashion it will enable a collective view of enterprise information. Repositories built on DNA technology will, in addition, provide a single distributed platform/framework for additional document/content/information services including indexing, metadata creation, search, versioning, and records management, resulting in the warfighter's ability to take full advantage of all available pertinent information in a rapid and flexible manner.

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- Today's warfighters are overwhelmed with information, but have difficulty finding and integrating the right fragments of data they need from the vast array of disparate data sources available. Military systems including command and control, intelligence, information assurance, special operations, maintenance and logistics are plagued by non-integrated, heterogeneous, legacy information systems. The Data Integration and Exploitation SystEm that Learns (DIESEL) effort will develop a new suite of information integration techniques for the warfighter. The fundamental problem is that information systems are, necessarily, developed independently using different software conventions, data types, semantic models and assumptions about their use. All of these "stovepipe" systems come together at many levels of command, where they must interoperate and share data. A new suite of intelligent information integration tools are needed – ones that could *learn* to automatically ingest and understand new information systems as they occur and learn to semi-automatically map/integrate those new systems into the existing information environment. Recent developments in web services, DAML, and the Semantic Web have created the right infrastructure on which to develop this information integration technology. The ultimate utility of better information integration is better and faster decisions; the result of warfighters having the right information they need at the right time.

(U) Program Plans:

– Digital Network Archive (DNA)

FY 2007 Accomplishments:

-- Created web interfaces to a digital object repository enabling networked access.
-- Completed initial design work for implementing identity management, security, and privacy controls.
-- Launched a trial system demonstrating utilization of persistent digital object identification across multiple protocols and application platforms.

FY 2008 Plans:

-- Extend the digital repository architecture to enable ubiquitous access from multiple devices while providing secure, effective, document sharing.
-- Develop a prototype repository system with military applicability that can accommodate thousands of users and further facilitate an open, extensible, and vendor-independent architecture.
-- Research and develop technologies to address issues of access control, security, indexing and search, metadata creation and maintenance, and version tracking.

FY 2009 Plans:

-- Continue to develop a variety of innovative services for the repository architecture and prototype subsystems to address such issues as access control, security, indexing and search, metadata creation and maintenance, and version tracking.

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-- Bring on line multiple, interoperating, digital repositories demonstrating the feasibility, and advantages of the digital repository architecture.
-- Demonstrate controlled, secure access across administrative domains, and its potential for integrating diverse, distributed information bases.

– Data Integration and Exploitation SystEm that Learns (DIESEL)
FY 2008 Plans:
-- Incorporate scientific, technical, and military domain knowledge in emerging web-service, semantic, and knowledge-base information integration infrastructure technologies including XML, DAML, and OWL.
-- Demonstrate preliminary ideas for learning-based entity resolution, data source modeling, and schema mapping technologies.
-- Demonstrate “best effort integration” methods.
-- Review commercial technical baseline.
-- Describe military needs and representative challenge problems.
-- Develop multimedia database techniques to store the raw content and associated metadata to enable search, correlation, and analysis.
-- Develop advanced automatic techniques for analyzing and correlating a wide variety of multimedia data with an emphasis on specific algorithms that can derive key analytic features without solving the general scene analysis problem.
FY 2009 Plans:
-- Develop learning-based semantic integration techniques including brokering techniques to dynamically discover and compose information services “on the fly” to fit the user’s mission, situation, preferences, available data, and context in general.
-- Develop techniques for representing and composing services that use task learning to discover, represent and access new information sources.
-- Develop tools to easily add new components and services including machine learning techniques to induce schema ontology mappings.
-- Develop machine learning-based techniques to semi-automatically ingest, understand, and “wrap” legacy information sources.
-- Develop data discovery techniques to automatically search multimedia databases, semi-structured collections of data, and unstructured text collections for correlations and actionable intelligence.
-- Create new multimedia analysis algorithms with an emphasis on using context to determine feature attributes.

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	FY 2007	FY 2008	FY 2009
Improved Warfighter Information Processing (IWIP)	1.147	0.000	0.000

(U) The Improved Warfighter Information Processing (IWIP) technology thrust developed technologies to enhance the warfighter's and commander's information management capacities and improve decision-making performance. The program developed the means, devices and infrastructure necessary to assess the warfighter's or commander's cognitive status in real time, and used adaptive strategies specific to his/her status to improve information processing and decision-making.

(U) Program Plans:
FY 2007 Accomplishments:
- Deployed to Commander Navy Europe/Commander Sixth Fleet (CNE-C6F) Navy Europe Plans and Operations Command Center (NEPOCC) and Theater Maritime Fusion Center (TMFC).

(U) Other Program Funding Summary Cost:

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2008
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Biological Warfare Defense PE 0602383E, Project BW-01

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	99.926	72.101	66.291	55.398	50.936	42.021	42.020
Biological Warfare Defense Program BW-01	99.926	72.101	66.291	55.398	50.936	42.021	42.020

(U) Mission Description:

(U) DARPA's Biological Warfare Defense project is budgeted in the Applied Research Budget Activity because its focus is on the underlying technologies associated with pathogen detection, prevention, treatment and remediation. This project funds programs supporting revolutionary new approaches to biological warfare (BW) defense and is synergistic with efforts of other government organizations.

(U) Efforts to counter the BW threat include countermeasures to stop pathophysiologic consequences of biological or chemical attack, host immune response enhancers, medical diagnostics for the most virulent pathogens and their molecular mechanisms, tactical and strategic biological and chemical sensors, advanced decontamination and neutralization techniques, and integrated defensive systems. This program also includes development of a unique set of platform technologies that will dramatically decrease the timeline from military threat detection to countermeasure availability.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Unconventional Therapeutics	35.000	26.235	26.470

(U) This thrust is developing unique and unconventional approaches to ensure that soldiers are protected against a wide variety of naturally occurring, indigenous or engineered threats. Past successes in this effort have come from developing therapeutics that are designed to work against broad classes of pathogens. This has led to several significant transitions, a separate thrust in Anthrax countermeasures, and most recently a program at Defense Threat Reduction Agency (DTRA) that directly capitalizes on previous DARPA investments. Work in this area has also uncovered new approaches to therapeutics that, rather than attacking specific pathogens, enhance innate human immune mechanisms against broad

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classes of pathogens. Not only will these approaches be more effective against known pathogens, they also promise to offer substantial protection against unknown pathogens including engineered pathogens and emerging pathogens from third-world environments.

(U) A current emphasis is on the discovery and development of technologies that will allow a rapid response (within weeks) to unanticipated threats, whether they are naturally encountered emerging diseases or agents from intentional attack. This thrust has a goal of radically transforming the protein design process by researching and developing new mathematical and biochemical approaches to the in silico design of proteins with specific functions. This program is also developing an interactive and functional in vitro human immune system using tissue engineering. This "immune system" will be able to test the efficacy of vaccines against threat agents that, at the present time, can only be tested in animal models, thus significantly decreasing the time needed and increasing the probability of success for biological warfare vaccine development. An additional focus is the development of entirely new technologies that will allow the rapid, cost-effective manufacture of complex therapeutic proteins such as monoclonal antibodies and vaccine antigens; these technologies will reduce the time for biologics manufacture from years (or even decades) to only a few weeks.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated that artificial human immune system simulates the actual human immune response to both viral and bacterial vaccines.
- Demonstrated in vitro antibody class switching in human lymphocytes exposed to a vaccine.
- Demonstrated primary antibody, recall antibody and naïve responses to a variety of vaccines of relevance to military force protection.
- Demonstrated that engineered organic nanoparticles elicit an immune response (antibody response, B-cell activation).
- Selected approaches to achieve accelerated manufacturing goals.
- Demonstrated single chain antibody synthesis in fungal and bacterial bio-industrial systems.
- Developed transfection methodologies for high throughput modification of plants.
- Optimized viral system to introduce vaccine/antibody coding sequences into shrimp.
- Developed approaches to ensure sufficient post-transcriptional processing in bacterial and fungal systems.
- Initiated a study to determine potential structure of antibodies.

FY 2008 Plans:

- Demonstrate a manufacturing rate for a 40µg vaccine $\geq$ 1 dose / (L * wks) and 400mg mAB $\geq$ 0.025 doses/(L * wks).

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- Demonstrate purity, structural fidelity, and functionality of biologics produced in a variety of manufacturing platforms (crustacean, fungal, prokaryote and plants).
- Predict historical failed vaccines using only the artificial human immune system.
- Complete transition of vaccine technology to government and commercial partners.
- Develop approaches for on-site battlefield synthesis of small molecule therapeutics, including antibiotics.
- Merge molecular imprinting with organic nanoparticles to generate functional viral replicates.
- Demonstrate fusogenic properties of antibodies.

FY 2009 Plans:

- Demonstrate biologics manufacture rates 10x improved from FY 2008, at the 30L scale.
- Demonstrate pathway to protein structure, function, purity, and cost to meet end of program milestones.
- Develop tools that will predict pathogen mutations before they occur and develop appropriate medical countermeasures in advance of the emergence of new threat agents.

	FY 2007	FY 2008	FY 2009
External Protection	6.000	1.500	5.000

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

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated proof of concept for active textiles that can decontaminate biological agents including dormant spores.
- Demonstrated a novel polyurethane coating system with the ability to continuously decontaminate its surface when exposed to biological agents including spores. The coating system is 100% compatible with the military chemical agent resistant coatings (CARC) currently being used on military vehicles.

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– Demonstrated a polymeric resin compatible with cold-plasma deposition that can self-decontaminate when exposed to biological agents such as spores.

FY 2008 Plans:

– Optimize the active textile cells for improved gas generation efficiency and lifetime, sporacidal ability, and cell reliability.
– Develop additives (surface active biocides, nutrients, microspheres) into a spray coatable CARC resin to enhance biocidal effect at low humidity.
– Develop atmospheric pressure cold plasma deposition processes to deposit biocidal materials that are 100% compatible with semiconductor devices and capable of killing spores.

FY 2009 Plans:

– Scale-up production of active self-decontaminating textiles to produce large bolts of cloth for field testing.
– Demonstrate feasibility of producing large area textiles that can actively decontaminate a surface or structure subjected to biological agents on demand.
– Field test the optimized self-decontaminating polyurethane based CARC on military vehicles at Dugway Proving Grounds using BW simulants.
– Scale up the deposition processes to handle larger pieces of electronics.
– Demonstrate the efficacy and compatibility of the biocides and process by demonstrating coating of military tactical radios.
– Develop an integrated thermal model of a combatant under operational conditions including bioheat generation, internal convective (blood) and conductive (tissue) heat transfer, and coupling to ambient heat baths by radiation, conduction, evaporation, and convection.
– Develop fabrics and garment architectures that allow tuning of evaporative and convective heat transfer from the body behind a chemically impermeable external shell.

	FY 2007	FY 2008	FY 2009
Advanced Diagnostics	20.193	16.539	11.527

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

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

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated utility of devices to detect exhaled volatile organic compounds in breath.
- Demonstrated the capability to mechanically and reversibly alter the protein structure of an assay system so as to alter the sensitivity and specificity of analyte detection.
- Initiated clinical studies to identify pre-symptomatic indicators of impending illness.
- Developed platforms for rapid assessment of biological samples for pre-symptomatic indicators of illness.
- Completed initial evaluation of technologies to allow rapid, non-invasive and inexpensive assessment of radiation exposure in humans.

FY 2008 Plans:

- Identify parameters that indicate presence of a viral infection before symptoms occur.
- Develop algorithms that can predict illness from rhinovirus prior to onset of symptoms.
- Develop medical countermeasures that alleviate radiation exposure in experimental models.
- Complete evaluation of volatile organic compounds in the breath of explosive handlers.
- Demonstrate Receiver Operating Curve (ROC) for detection of explosive handlers and bystanders.
- Demonstrate reversible mechanical alterations in protein structure that yield a 10-fold change in affinity to biological, chemical and environmental agents.
- Complete evaluation of non-invasive rapid biodosimeters that can be used to triage large populations in the event of a large radiological/nuclear event.

FY 2009 Plans:

- Refine predictive model of impending illness to increase the probability of detection and reduce probability of false alarms.
- Confirm predictive model of impending illness accuracy in large sample-size, warfighter relevant populations.
- Evaluate radiation technologies at Air Force Radiobiology Research Institute (AFRRI) in a live fire test to identify best biodosimeters.

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	FY 2007	FY 2008	FY 2009
Sensors	21.733	14.327	12.000

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

(U) The overall goal of DARPA's Handheld Isothermal Silver Standard Sensor (HISSS) program was to develop a sensor that is capable of detecting the entire biological warfare threat spectrum (bacteria, DNA viruses, RNA viruses and protein toxins) with the same "silver standard" specificity as current laboratory techniques, but in a fast, reliable, handheld unit. Today, this standard is achieved for DNA and RNA threats using polymerase chain reaction, which is slow because of the associated temperature cycling. For proteins, the standard is met using Enzyme Linked Immunosorbent Assay (ELISA), which requires skilled laboratory technicians to complete. The equipment required for these tests is bulky and difficult to use under field conditions. Under HISSS, DARPA was to 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) The Spectral Sensing of Bio-Aerosols (SSBA) program involved the active probing of bioaerosols with electromagnetic (EM) energy, which holds the promise of extremely fast, and potentially long-range, detection and identification of bio agents. Only a small portion of the EM spectrum is exploited in today's trigger sensors (e.g., optically based particle sizers, sometimes enhanced with fluorescence measurements). However, anecdotal evidence suggests that other portions of the spectrum may offer substantial improvement in trigger sensors, as well as potentially agent-specific discrimination capability. Various types of spectra in the visible, infrared, and ultraviolet (UV) wavelengths were measured for prototype systems development. Additional spectral information such as UV fluorescence lifetime and single particle mass spectroscopy was also evaluated. An aerosol testbed has been developed to provide calibrated exposures of threat agent simulants and complex clutter mixtures for sensor performance evaluation.

(U) The goal of the Femtosecond Adaptive Spectroscopy Techniques for Remote Agent Detection (FASTREAD) program is to provide a capability to detect biological agents at standoff distances. This goal will be accomplished by performing coherent nonlinear optical spectroscopy, laser pulse shaping techniques, and adaptive optics coupled to strategies that optimize the return signal from the agent under interrogation. By

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using short pulse lasers in conjunction with coherence effects, both the spectral and temporal information contained in the backscattered signal can be exploited, enabling identification of specific agents and providing a mechanism to adapt the system to new agents.

(U) The Hyperadsorptive Atmospheric Sampling Technology (HAST) program will develop systems that permit exhaustive, accurate, and economical collection of atmospheric trace constituents to support chemical mapping of urban and military environments. The system, which integrates three technical components, will demonstrate materials, packaging, and extraction technologies that sample atmospheric impurities whose concentration ranges from 20 parts per trillion to 200 parts per million by volume from 100 liter-atmospheres of gas in less than five minutes.

(U) Program Plans:

– Handheld Isothermal Silver Standard Sensor (HISSS)
  FY 2007 Accomplishments:
  -- Components were designed and fabricated including: 1) a handheld user interactive device; 2) a field-swappable cartridge interface module with onboard optical detection hardware; and 3) a disposable cartridge that incorporated sample preparation , stabilized lyophilized reagents, and optical windows for assay readout.
  -- Stabilized reagents were developed for fieldable cartridges.

– Spectral Sensing of Bio-Aerosols (SSBA)
  FY 2007 Accomplishments:
  -- Completed fabrication of two prototype trigger bioaerosol sensors; one sensor exploits mass spectrometry for single particle identification and the other exploits multi-spectral fluorescence for simulant identification in bulk.
  -- Testbed demonstrated at least one week of continuous and autonomous aerosol challenges consisting of at least eighty types of complex environmental clutter backgrounds that represented seven outdoor/indoor locations used for sensor prototype testing.
  -- Characterized sensor prototype behavior in operational environments against four classes of bio-agent aerosol simulants.

– Femtosecond Adaptive Spectroscopy Techniques for Remote Agent Detection (FASTREAD)
  FY 2007 Accomplishments:
  -- Demonstrated detection of dipicolonic acid (chemical associated with anthrax) by Coherent Antistokes Raman Spectroscopy (CARS) at a range of 200 meters using femtosecond lasers and a guide star.

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-- Obtained in the laboratory the Coherent Antistokes Raman signature of a number of molecules and determined the Receiver Operating Curve (ROC) at a number of signal to number (S/N) and signal to curve (S/C) ratios.

FY 2008 Plans:

-- Expand FASTREAD detection range using the CARS technique to 1 km.

-- Lower FASTREAD false alarm rate by an order of magnitude at a fixed probability of detection of 0.99.

FY 2009 Plans:

-- Expand FASTREAD detection range using the CARS technique to 3 km without using a guide star while detecting dipicolonic acid at 100 agent containing particles per liter of atmosphere while lowering the false alarm rate by an order of magnitude at a fixed probability of detection of 0.999.

– Hyperadsorptive Atmospheric Sampling Technology (HAST)

FY 2008 Plans:

-- Demonstrate materials, packaging, and extraction technologies that sample atmospheric impurities.

FY 2009 Plans:

-- Complete a light-weight trace element system for indexing for one hundred atmospheric samples as well as demonstrating GPS geolocation.

	FY 2007	FY 2008	FY 2009
Threat Agent Cloud Tactical Intercept Countermeasure (TACTIC)	10.000	10.000	8.430

(U) The Threat Agent Cloud Tactical Intercept and Countermeasures (TACTIC) program will develop and demonstrate the capability to 1) rapidly detect, classify 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 intended target. The TACTIC program will develop a prototype system having an integrated approach for the classification/identification (CI) and countermeasure (CM) of aerosolized CWA/BWA threat clouds. The TACTIC system prototype will be evaluated in controlled breeze tunnel testing environments with variations in range, concentration and wind speed. Upon successful completion of the preliminary design and critical design reviews, a prototype system will be built to demonstrate an effective CI and CM systems capability in open air tests. A memorandum of agreement (MOA) is in place with the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) for transitioning this capability to the Army.

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(U) Program Plans:

FY 2007 Accomplishments:

- Investigated technologies to defeat CWA/BWA cloud so as to eliminate the threat to unprotected war-fighters.
- Investigated technologies for stand-off assays that rapidly identify CWA/BWA threat clouds.

FY 2008 Plans:

- Develop models of CI/CM subsystem performance for open air tests.
- Conduct trade studies between competing CI/CM subsystems.
- Conduct in-house laboratory tests to validate performance of CI/CM subsystem components.

FY 2009 Plans:

- Integrate optimal CI and CM components into a prototype system.
- Test prototype system in scaled aerosol breeze tunnel test chamber.
- Transition program to JPEO-CBD.

	FY 2007	FY 2008	FY 2009
Mission-Adaptable Chemical Sensors (MACS)	6.000	3.000	2.864

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

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(U) Program Plans:
FY 2007 Accomplishments:
- Completed subsystem designed for the sample acquisition, frequency management, and terahertz-generation modules, for subsequent integration within the MACS system.
- Completed evaluation of basic circuitry, and began fabrication of subsystem components.

FY 2008 Plans:
- Complete fabrication and integration of the modules.
- Conduct testing and evaluate system performance.
- Complete development of a portable sensor with 100 ppt sensitivity, false-alarm rate less than 0.1/day.

FY 2009 Plans:
- Extend the number of analytes assayed into hundreds, with automatic identification using computer lookup.
- Include fractionization of test within the sample acquisition module for improved sensitivity performance.
- Build a compact, fully portable, highly sensitive sensor system.

	FY 2007	FY 2008	FY 2009
Detecting Emerging Classes of Explosives	1.000	0.000	0.000

(U) This effort researched technologies for emerging classes of explosives.

(U) Program Plans:
FY 2007 Accomplishments:
- Explored technologies for emerging classes of explosives.

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	FY 2007	FY 2008	FY 2009
Biomedical Engineering Initiative	0.000	0.500	0.000

(U) Program Plans:
FY 2008 Plans:
– Develop biosensors to identify blood-borne biomarkers of tissue trauma that convey information concerning injury severity and prognosis.

(U) **Program Change Summary:** *(In Millions)*	**FY 2007**	**FY 2008**	**FY 2009**
Previous President's Budget	112.814	99.137	106.982
Current Budget	99.926	72.101	66.291
Total Adjustments	-12.888	-27.036	-40.691
Congressional program reductions	-10.000	-27.536	
Congressional increases	0.000	0.500	
Reprogrammings	0.000		
SBIR/STTR transfer	-2.888		

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(U) Change Summary Explanation:

FY 2007	The decrease reflects the SBIR/STTR transfer and Section 8043 Rescission.
FY 2008	The decrease reflects a PE execution adjustment, the cancellation of the Spectral Sensing Bio-Aerosols program, and reductions for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions, offset by a congressional add for Biomedical Engineering Initiative.
FY 2009	The decrease reflects draw down of BWD efforts as programs transition directly to elements of the DoD (i.e., the Army, DTRA) that have cognizance over Service BWD materials and systems, and reclassification of several sensor development programs to protect the technological attributes of the systems.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	300.721	335.967	371.481	355.591	322.212	324.712	326.393
Naval Warfare Technology TT-03	35.728	36.676	38.893	40.125	40.109	40.109	40.109
Advanced Land Systems Technology TT-04	49.853	60.286	82.421	83.580	79.752	80.147	79.354
Advanced Tactical Technology TT-06	103.715	113.550	114.421	84.028	59.820	59.820	60.314
Aeronautics Technology TT-07	58.505	52.756	58.158	64.856	67.486	68.105	70.086
Network Centric Enabling Technology TT-13	52.920	72.699	77.588	83.002	75.045	76.531	76.530

(U) Mission Description:

(U) This program element is budgeted in the Applied Research Budget Activity because it supports the advancement of concepts and technologies to enhance the next generation of tactical systems. The Tactical Technology program element funds a number of projects in the areas of Naval Warfare, Advanced Land Systems, Advanced Tactical Technology, Aeronautics Technology and Network Centric Enabling technologies.

(U) The Naval Warfare Technology project develops advanced enabling technologies for a broad range of naval requirements. Technologies under development will increase survivability and operational effectiveness of small and medium surface vessels in rough seas and demonstrate advanced technologies for hypersonic flight. New areas to be investigated include ship self defense techniques, novel underwater propulsion modalities, vessels for estuary and riverine operations and predictive tools for small craft hydrodynamic design.

(U) The Advanced Land Systems project is developing technologies for enhancing U.S. military effectiveness and survivability in operations ranging from traditional threats to military operations against irregular forces that can employ disruptive or catastrophic capabilities, or disrupt stabilization operations. The emphasis is on developing affordable technologies that will enhance the military's effectiveness while decreasing the exposure of U.S. or allied forces to enemy fire.

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

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

(U) The Network Centric Enabling Technology project funds sensor, signal processing, detection, tracking and target identification technology development required for true network-centric tactical operations. Technologies developed in this project will enable localized, distributed and cross-platform collaborative processing so that networks of sensors can rapidly adapt to changing force mixes, communications connectivity and mission objectives. Operational benefits will be smaller forward deployment of image and signal analysts, consistent integration of target and environment information, and flexible operational tactics and procedures for finding evasive targets in difficult environments.

(U) **Program Change Summary:** *(In Millions)*	**FY 2007**	**FY 2008**	**FY 2009**
Previous President's Budget	359.936	374.717	436.842
Current Budget	300.721	335.967	371.481
Total Adjustment	-59.215	-38.750	-65.361
Congressional program reductions	-35.000	-49.550	
Congressional increases	0.000	10.800	

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Reprogrammings	-15.000
SBIR/STTR transfer	-9.215

(U) Change Summary Explanation:

FY 2007	Decrease reflects a departmental reprogramming (PA 07-18) and the SBIR/STTR transfer.
FY 2008	Decrease reflects reductions for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions, offset by congressional adds CEROS and Optinet Sensor System.
FY 2009	Decreases reflect programs ending or transitioning in Advanced Land Systems Technology (NetEx, Sticky Flares), Advanced Tactical Technology (High Power Fiber Lasers, Air Laser), Aeronautics Technology (Hypersonics Demonstration), and rephasing of Network Centric programs.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research			R-1 ITEM NOMENCLATURE Tactical Technology PE 0602702E, Project TT-03				
COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Naval Warfare Technology TT-03	35.728	36.676	38.893	40.125	40.109	40.109	40.109

(U) Mission Description:

(U) The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. Enabling and novel technologies include concepts for expanding the envelope of operational naval capabilities such as drag reduction, ship stability, hypersonic missiles, logistically friendly distributed lighting systems, ship self defense techniques, novel underwater propulsion modalities, vessels for estuary and riverine operations, high speed underwater vessels, improved techniques for underwater object detection and discrimination, long endurance unmanned surface vehicles, and high bandwidth communications.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Friction Drag Reduction	5.125	3.700	0.000

(U) The Friction Drag Reduction program has developed and demonstrated physics-based, engineering design tools that will predict additive-based friction drag reduction on Navy surface ships. To date, the program has developed the capability to predict how turbulent flows are modified by the presence of polymers and air injection and has identified hull designs on which air layer drag reduction would be cost-effective. Air injection effects were confirmed with small-scale physical experiments and tests in a large-scale facility at ship-relevant scales. Large scale experiments have been conducted on a thirteen meter long flat plate at the U.S. Navy's William B. Morgan Large Cavitation Channel, with separate tests for the polymer and air injection. Additionally, polymer and air film injections were tested with simulated surface roughness to assess the effects caused by biofouling on hulls.

(U) Program Plans:

FY 2007 Accomplishments:

– Verified effects of air and polymer injection on flat plate tests at representative ship scales and speeds.

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– Experimentally determined how additive-based friction drag reduction is influenced by the presence of significant surface roughness.

FY 2008 Plans:

– Evaluate approaches and hull designs suitable for realistic at-sea tests to evaluate the effect of sea states, maneuvering conditions, biofouling, ship curvature and pressure gradients on injection and additive based drag reduction approaches.

	FY 2007	FY 2008	FY 2009
Center of Excellence for Research in Ocean Sciences (CEROS)	5.600	10.000	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 potential Department of Navy transition partners. Major research areas of interest have included shallow water surveillance technologies, sensor communications, ocean environmental preservation, new ocean platform and ship concepts, ocean measurement instrumentation, and unique properties of the deep ocean environment. CEROS has been funded through Congressional earmarks and funds targeted for CEROS were not included in the President's Budget request.

(U) Program Plans:

FY 2007 Accomplishments:

– Completed projects started in FY 2006.
– Selected projects for FY 2007 funding.
– Contracted for selected projects and monitored progress of ocean related technologies of high interest to the DoD.

FY 2008 Plans:

– Complete projects started in FY 2007.
– Select projects for FY 2008 funding.
– Contract for selected projects and monitor progress of ocean related technologies of high interest to the DoD.

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	FY 2007	FY 2008	FY 2009
Acoustic Arrays for Torpedo Defense	2.000	1.306	0.000

(U) The Acoustic Arrays for Torpedo Defense program will demonstrate the feasibility of using an array of transducers to form a destructive pressure pulse capable of disabling an enemy's torpedo. Of critical importance is the ability to accurately predict non-linear pressure pulse propagation effects and corresponding timing delays used during pressure pulse generation and beamforming. Additionally, the beamformed pressure pulse must be of sufficient amplitude and duration to destroy a torpedo at tactically significant ranges.

(U) Program Plans:

FY 2007 Accomplishments:

- Designed, developed, and tested a two-element transducer module.
- Completed design improvements on second generation transducer module.
- Successfully tested second generation transducer module.

FY 2008 Plans:

- Develop scaled prototype 8x2-element transducer array.
- Sucessfully beamform pressure pulses.
- Validate non-linear pulse propogation model for extended ranges.
- Conduct demonstration of pulse focusing and beam-steering with prototype 8x2-element transducer array.

	FY 2007	FY 2008	FY 2009
Unique Propulsion Techniques	2.628	1.000	0.000

(U) The Unique Propulsion Techniques program will develop a novel underwater propulsion technology for Unmanned Underwater Vehicles (UUV) and other underwater platforms that require high maneuverability at low velocities. The propulsion mechanism of the electric eel may hold the key to this enabling technology. Electric eels using ribbon fin propulsion may be generating traveling chains of ring vortices, which give more momentum transfer than simply pushing the same quantity of fluid with no structure. The objective of the program is to develop a ribbon fin

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propulsion system and demonstrate the increased low velocity power efficiency and maneuverability of an actual underwater platform. The fundamental technical challenges include 1) determining if the traveling wave is structured to maximize thrust, 2) determining the structure of the fluid flow imparted by the ribbon fin, 3) determining how to implement a flexible ribbon structure with sufficient power and controllability to be useful, and 4) determining how to attach such a structure to a rigid body and integrate it with other control surfaces to gain additional degrees of freedom.

(U) Program Plans:
FY 2007 Accomplishments:
- Accurately modeled the physics of ribbon fin propulsion and created predictive design tools.
- Designed and demonstrated a ribbon fin propulsion system on an appropriately scaled surrogate platform.

FY 2008 Plans:
- Complete final testing and documentation of technologies.

	FY 2007	FY 2008	FY 2009
Riverine Crawler Underwater Vehicle	2.013	2.500	0.000

(U) The Riverine Crawler Underwater Vehicle program will develop unmanned underwater vehicle concepts that can transit underwater in riverine and shallow water coastal environments and carry out surveillance/reconnaissance and deployment tasks in denied, sensitive or contested areas. The program will study means of operating an unmanned submerged craft in riverine shallow water areas (nominally at operational environment depths of <40ft) including rivers, estuaries and harbors involving challenging surface and sub-surface conditions such as obstructions, turbidity, wave action and currents. Novel means of navigation, propulsion and sensing will be required to operate autonomously in such environments. The effort will identify the promising vehicle types and examine the system and/or component element technologies required to support these vehicles.

(U) Program Plans:
FY 2007 Accomplishments:
- Performed concept of operations studies.

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FY 2008 Plans:
- Identify enabling technologies that support an autonomous underwater vehicle concept that is capable of operating in shallow water (<25 feet) including riverine, coastal and harbor environments.
- Develop concept designs to enable a new sub-surface capability for riverine and other shallow water operations.

	FY 2007	FY 2008	FY 2009
Wideview	1.158	3.500	0.000

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

(U) Program Plans:
FY 2007 Accomplishments:
- Investigated feasibility of adapting technology.

FY 2008 Plans:
- Complete feasibility study and document lessons learned.

	FY 2007	FY 2008	FY 2009
Super-Fast Submerged Transport	8.000	12.100	25.893

(U) The Super-Fast Submerged Transport program (Underwater Express) will explore the application of supercavitation technology to underwater vehicles, enabling high speed transport of personnel and/or supplies. The inherent advantages of traveling underwater are: the ability to transit clandestinely, (no radar or visible signature), and avoidance of rough sea conditions that may limit or deny mission execution. Supercavitation places the vehicle inside a cavity where vapor replaces the water, and drag due to fluid viscosity is reduced by orders of magnitude, thus reducing the power requirement dramatically. This program will use modeling, simulation, and experiments and testing to

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develop the understanding of the physical phenomena associated with supercavitation and the application to underwater vehicles. Innovative failsafe controls will be required for stability and maneuverability at speed.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed models and simulations for cavitator performance, including cavity generation and stability.
- Conducted subscale experiments and developed understanding of cavity geometry over a range of operating conditions.
- Developed and experimentally verified methods for generating stable cavities over a range of operating conditions.
- Developed initial design trade critical issues including sizing estimates for a scale and full-scale vehicle.
- Modeled and analyzed design vehicle system stability and vehicle control issues.

FY 2008 Plans:

- Conduct modeling, simulations, and experiments to develop an understanding of cavity and vehicle interactions and the effect of these interactions on vehicle design, control and stability.
- Continue development of vehicle design including propulsion system design and integration, and design, fabrication and testing of a scaled prototype vehicle.
- Commence design, fabrication, and testing of a scaled prototype vehicle.
- Model, simulate, and experimentally measure vehicle maneuvering and body forces in a controlled facility.
- Develop vehicle and cavity scaling relationships.

FY 2009 Plans:

- Design, fabricate and test a scaled prototype vehicle.
- Analyze prototype performance for speed, power and stability.
- Develop vehicle and cavity scaling relationships.

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	FY 2007	FY 2008	FY 2009
Distortion-free Seeing Through the Air/Water Interface	0.000	2.570	0.000

(U) Images seen through an air-water interface are distorted by multiple refractions from the water surface. This program will develop high-resolution imaging and image exploitation technology to provide new capabilities for detection and discrimination of objects such as surface crafts and underwater objects, which could significantly improve near-surface operations and safety.

(U) Program Plans:
FY 2008 Plans:
- Conduct experiments and scale testing of imaging algorithms.
- Conduct modeling to characterize resolution, image quality, and performance in various water qualities and optical conditions.

	FY 2007	FY 2008	FY 2009
Extremely Long Endurance Unmanned Surface Vehicle (ELEUSV)	0.000	0.000	4.000

(U) The Extremely Long Endurance Unmanned Surface Vehicle (ELEUSV) program will develop technologies that allow a robotic naval vessel to operate for years with minimal human interaction beyond tasking. This will enable a significant expansion of naval presence and will provide potential advantages in counter mine and anti-submarine warfare, emergency response and rescue operations, and intelligence gathering. Technologies to be explored include energy harvesting from the environment in order to power vessels for multi-year periods, command and control systems to enable global operations of remotely supervised systems, and de-fouling and other self-maintenance capabilities. The ELEUSV program will also investigate unique payload systems that will benefit from the extended periods of uninterrupted operations.

(U) Program Plans:
FY 2009 Plans:
- Conduct analysis of ELEUSV deployment time limiting factors.
- Identify core technologies required to enable multi-year operational deployments.

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– Develop operational system concept designs and technology integration plan.

	FY 2007	FY 2008	FY 2009
Broad Ocean Demining	0.000	0.000	4.000

(U) The Broad Ocean Demining program will develop and demonstrate system capabilities to counter maritime Improvised Explosive Devices (IEDs) and protect global military and economic maritime interests from disruption. By enabling the rapid detection of mines, mining operations, and other asymmetric IEDs and developing methods of rapidly clearing those threats from critical areas, the program will increase assured operations of military and non-military ocean traffic. Additionally, the program will explore innovative distributed systems that can escort ships and allow them to detect, avoid, and if necessary, neutralize these threats while underway. Technical elements include surveillance networks that can be rapidly emplaced and affordably monitored, improved detection and neutralization techniques, and robotic systems that can carry out the search and neutralization missions with minimal support from military ships.

(U) Program Plans:
FY 2009 Plans:
– Define prioritized threat vectors based on potential to disrupt military and commercial shipping.
– Identify core technologies to enable affordable and effective defeat of these threats.
– Develop broad ocean demining architectural concept and system integration plan.

	FY 2007	FY 2008	FY 2009
High Bandwidth Maritime Communications	0.000	0.000	5.000

(U) The High Bandwidth Maritime Communications program will develop and exploit nonlinear optical processes to efficiently translate an arbitrary optical waveform from one wavelength band to another, allowing use of commercial laser components signal-processing techniques, and advanced photonic technology in underwater communications. This will increase underwater communications performance (throughput and range) by over an order of magnitude from what is achievable today because of the use of high performance commercially available components

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and telecommunications signal processing technology. Significant technical obstacles include up- and down-conversion efficiencies and severe attenuation in water.

(U) Program Plans:
FY 2009 Plans:
- Develop technologies to address acceptance angle limitations.
- Design and fabricate photonic frequency converter.
- Measure converter photon conversion efficiency and gain in laboratory environments.
- Model system performance in simulated ocean environment.

	FY 2007	FY 2008	FY 2009
Surface Warfare Automated Shiphandling (SWASH)	2.728	0.000	0.000

(U) The Surface Warfare Automated Shiphandling (SWASH) program examined technologies to increase survivability and operational effectiveness of small and medium naval surface vessels in rough seas. Currently, vessels are at the mercy of ocean waves, and when waves become sufficiently large, damage and capsizing can occur. SWASH sought to enable safe operations in an expanded sea state envelope by combining detailed wave sensing and prediction with improved understanding of vessel dynamics in a control system that provides optimum course and speed to the vessel's rudder and engines.

(U) Program Plans:
FY 2007 Accomplishments:
- Refined prediction capability for ocean wave fields.

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	FY 2007	FY 2008	FY 2009
Hypersonics Flight Demonstration (HyFly)	5.476	0.000	0.000

(U) The Hypersonics Flight Demonstration program (HyFly) developed and demonstrated advanced technologies for hypersonic flight. The ultimate goal of the program was to demonstrate vehicle performance that could lead to an operational tactical surface launched missile range of 600 nautical miles. Specifically, the program demonstrated an F-15 launched missile configuration with a range of 400 nautical miles, a maximum sustainable cruise speed in excess of Mach 6, and the ability to accurately terminate the missile on a GPS guided impact target. Technical challenges included the scramjet propulsion system, lightweight, high-temperature materials for both aerodynamic and propulsion structures, and guidance and control in the h**y**personic flight regime. Recently demonstrated performance in ground testing of the dual combustion ramjet engine coupled with advances in high temperature, lightweight aerospace materials were enabling technologies for this program. The core program focused on development and demonstration of capabilities requisite for an operational weapon. DARPA and the Navy have established a joint program to pursue areas of the hypersonics program that would be relevant to maritime applications.

(U) Program Plans:

FY 2007 Accomplishments:

- Conducted captive carry, drop, boost performance and boost separation flight tests.
- Performed vehicle subsystems verification testing.
- Conducted flight weight vehicle environmental testing.
- Conducted flight weight engine component durability testing in operating engine environment.
- Conducted initial, low flight Mach (~Mach 4.0) flight-testing.
- Conducted flight testing.

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	FY 2007	FY 2008	FY 2009
High Efficiency Distributed Lighting (HEDLight)	1.000	0.000	0.000

(U) The High Efficiency Distributed Lighting (HEDLight) program fundamentally changed the design for lighting systems on U.S. military platforms to increase survivability, deployability, and maintainability. Current lighting systems use electrical distribution and the generation of light at the point-of-use. HEDLight remote source lighting uses centralized light generation and optically transports the light to the point-of-use. This allows the lighting system electrical circuitry and wiring to be concentrated, protected, and removed to the interior of the warship, thereby removing a source of vulnerability from the outer-envelope. Critical metrics 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 included 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 combined the light source, the optical coupler, and fiber-luminaire. A Memorandum of Agreement (MOA) is transitioning this technology to the Navy. An adjunct to the HEDLight program developed and demonstrated a state-of-art Assault Zone Landing Light, which solved the logistics and reliability issues of currently deployed lights.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed high efficiency full-spectrum light sources.
- Developed high efficiency optical coupling mechanisms.
- Developed high efficiency fiber-luminaries for distributed light transport.
- Developed an integrated high efficiency distributed lighting illuminator.
- Demonstrated a limited scale HEDLight system installed on two U.S. Navy ships.
- Developed and demonstrated the L-32 Assault Zone Landing (AZL-15) Lights, meeting the minimum lighting (visible and IR) and battery duration requirements and tested all system variations under operational field conditions.

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(U) Other Program Funding Summary Cost:

	FY 2007	FY 2008	FY 2009
Hypersonics Flight Demonstration			
PE 0602114N, PE 0603114N, PE 0603123N, Navy, Office of Naval Research	2.200	0.000	0.000

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Advanced Land Systems Technology TT-04	49.853	60.286	82.421	83.580	79.752	80.147	79.354

(U) Mission Description:

(U) This project is developing technologies for enhancing U.S. military effectiveness and survivability in operations ranging from traditional threats to military operations against irregular forces that can employ disruptive or catastrophic capabilities, or disrupt stabilization operations. The emphasis is on developing affordable technologies that will enhance the military's effectiveness while decreasing the exposure of U.S. or allied forces to enemy fire.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Novel Sensors for Force Protection	9.992	7.071	7.000

(U) The Novel Sensors for Force Protection program is exploring and developing novel methods that will contribute to enhanced protection of U.S. warfighters and address hostile situations encountered by U.S. warfighters in the Global War on Terrorism, Operation Enduring Freedom and Operation Iraqi Freedom. The intent is to enhance the ability of U.S. warfighters to sense the presence of explosives or shielded nuclear materials, as well as enhance the ability to identify individuals involved in the manufacture and/or use of these materials.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed data processing techniques for quantification of emanation signatures.
- Determined the relative contribution of Major Histocompatibility Complex (MHC)-determined signatures and non-genetic background signals.

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FY 2008 Plans:
- Perform studies to identify the specific regions of the mouse and human genome associated with odorant production in mice and humans.
- Demonstrate a breadboard pulsed d(D,n) neutron source; with 1-5M neutron pulses at 5 KHZ; a flux of 10M neutrons/second with ion energies with >1.15Mev and forward scattered neutrons with a half cone angle of 80 degrees.

FY 2009 Plans:
- Develop and demonstrate a compact field portable directional neutron source for stand-off detection of explosives and for nuclear materials.
- Develop operational prototype for explosives detection in breath.

	FY 2007	FY 2008	FY 2009
Dynamic Optical Tags (DOTS)	0.545	1.897	0.000

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

(U) Program Plans:

FY 2007 Accomplishments:
- Demonstrated performance in the field at militarily useful data rates and ranges.

FY 2008 Plans:
- Develop airborne interrogation systems.
- Develop novel emplacement technologies.

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– Integrate and test components in a fully functional configuration.

	FY 2007	FY 2008	FY 2009
Guided Projectiles	9.319	3.857	6.000

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

(U) The program developed low-cost, non-imaging optical seeker/guidance technology exploiting technology development in the visible and infrared spectrum, designed to replace the current 60mm mortar fuse and improve firing precision. Additionally, research was done with explosives to improve the effectiveness of 60mm explosive rounds. The goal was to develop a 60mm projectile with the effectiveness of a 105mm high explosive projectile. In addition, the technology developed for the 60mm projectile was investigated for application to the 81mm and 120mm mortars to increase the accuracy and effectiveness of all fielded mortar rounds at a low cost. This program will now leverage the innovative low-cost optical seeker technology to develop an affordable fuse-guidance package that converts a conventional 81mm or 120mm mortar round into a precision-guided munition. This program will further extend this development to the development of laser-guided munition systems wing-dropped from tactical UAVs and guidable from the on-board laser designator to any target within the field of view (FOV) of the designator. Critical developments supporting this program include component or packaging development technologies that enable the guidance sensors and actuators to sustain the 20-40,000g peak launch stresses, and the development of guidance systems that integrate low-cost GPS and terminal laser lock-on.

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(U) Program Plans:

FY 2007 Accomplishments:

- Conducted laboratory shock testing to characterize the conditions experienced at launch and began the process of verifying internal component survivability.
- Developed an aerodynamic model of the 60mm mortar round. Validated this model through ballistic launch testing.
- Developed and fabricated 60mm controlled test vehicle (CTV) rounds to verify aerodynamic controllability in flight and survivability of internal components during launch. Conducted CTV launch tests verifying significant portions of the design.
- Completed successful bench testing for the semi-active laser seeker, fabricating and successfully bench testing its analog detector chip subcomponent.

FY 2008 Plans:

- Develop a low-cost optical seeker applicable to 81mm and 120mm mortar rounds and unmanned air vehicle (UAV)-borne munitions.
- Design and develop the other components of the fuse-guidance packages for these rounds, to include electronic and mechanical components, as well as guidance software.
- Perform system engineering activities to derive design requirements for integration and employment on tactical UAVs.

FY 2009 Plans:

- Fabricate and test seeker-guidance systems on large caliber (81mm or 120mm) mortar rounds.
- Demonstrate full system aerodynamic control and less than 10% reduction in maximum range.
- Demonstrate guided round accuracy.
- Begin integrating the UAV-borne rounds with the tactical UAV platforms selected to employ them.

	FY 2007	FY 2008	FY 2009
Networking Extreme Environments (NetEx)	2.995	1.000	0.000

(U) The Networking in Extreme Environments (NetEx) program will create a wireless networking technology for the military user that will enable robust connectivity in harsh environments (for example, areas prone to multipath interference such as urban settings where buildings and other structures cause RF energy to “bounce” off, in and amongst the buildings/structures) and support development of new and emerging sensor and communication systems. This program will develop an improved physical layer for networked communications based on a family of new

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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:

FY 2007 Accomplishments:

- Developed and demonstrated power-efficient UWB communication systems that can coexist with legacy systems and intentional jammers.
- Developed algorithms, protocols, and distributed control for robust, scalable ad-hoc networking that effectively shares the UWB channel among non-cooperating UWB systems.
- Demonstrated the application of the NetEx UWB-based communication network to a wireless intercom system for intra-vehicle squad-level communications.

FY 2008 Plans:

- Build prototype NetEx UWB-based communication network system and test in operationally relevant field demonstration.

	FY 2007	FY 2008	FY 2009
Magneto Hydrodynamic Explosive Munition (MAHEM)	3.035	3.126	2.400

(U) The Magneto Hydrodynamic Explosive Munition (MAHEM) program will demonstrate compressed magnetic flux generator (CMFG)-driven magneto hydrodynamically formed metal jets and self-forging penetrators (SFP) with significantly improved performance over explosively formed jets and fragments. Explosively formed jets (EFJ) and 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

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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 vehicles (potential defeat mechanism for a kinetic energy round), counter armor (passive, reactive, and active), mine countermeasures, and anti-ship cruise missile final layer of defense.

(U) Program Plans:

FY 2007 Accomplishments:

- Completed single compressed magnetic flux generator (CMFG) and magnetic hydrodynamic explosive munition (MAHEM) concept designs.
- Tested helical CMFG designs at low-power.

FY 2008 Plans:

- Develop MAHEM variants tailored to mission-specific requirements.
- Develop and conduct experiments to demonstrate feasibility of a self-contained MAHEM in the form of an AT4 shoulder-mounted munition.
- Conduct aerostability, setback, and jet penetration tests on the AT4 mockup.
- Evaluate alternative CMFG capabilities and effects

FY 2009 Plans:

- Test fire from AT4 tube to demonstrate aerostability and setback.
- Transition to munitions development centers.

	FY 2007	FY 2008	FY 2009
Compact Military Engines	2.430	1.170	0.000

(U) As military systems become more mobile, 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

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walls. The Compact Military Engines program will address various engine types and diverse missions. A goal of the program is to decrease the size of mobile electric power generators by a factor of ten. Improvements to electric generators for hybrid electric vehicles will increase vehicle range and endurance.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated critical technologies.
- Completed prototype engine design, manufacture, and assembly.

FY 2008 Plans:

- Test prototype engine to demonstrate continuous operation at substantial power levels.

	FY 2007	FY 2008	FY 2009
Crosshairs	10.900	14.400	12.000

(U) The Crosshairs program seeks to develop a vehicle mounted, threat detection, and countermeasure system that will detect, locate, and engage enemy shooters against a variety of threats to include bullets, Rocket Propelled Grenades (RPGs), Anti-Tank Guided Missiles (ATGMs), and direct fired mortars, both stationary and on the move. Threat identification and localization will be accomplished in sufficient time to enable both automatic and man-in-the-loop responses. Phase I of the program focused on initial development and testing of the Crosshairs sensor system. Phase IA culminated with a static live fire test to determine the most effective candidate sensor system. During Phase IB, enhancements were made to the sensor system for on the move performance, and on the move testing against multiple threats was conducted. DARPA and the U.S. Army Rapid Equipping Force (REF) have entered into an MOA for Phase IIA. Phase IIA consists of a moving demonstration of the hardened, packaged, and enhanced Phase I sensor system on two networked HMMWVs (Humvee), integration with candidate response systems, and testing and evaluation of the complete systems in relevant environments. The goal of Phase IIB will be to integrate the final Crosshairs system with an appropriate active protection system (APS).

(U) The Concept of Operations is to provide a military vehicle with a mounted detection and response system that operates both stationary and on the move. Bullets will be detected and localized using the acoustic DARPA-developed Boomerang v2.5 acoustic gunfire detection system. Radar detection of all other threats will be made using the Crosscue radar. The Crosscue radar is a dual mode, continuous wave, and pulsed

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Doppler radar, which will be used to determine range, velocity, and azimuth of the incoming threat. It is envisioned that the system will provide a significantly improved capability to detect and respond to incoming threats during hostile and peacekeeping operations in both urban and non-urban environments. Technology challenges include: low false alarm rate, algorithm development, high speed sensor and data processing for 360 degree azimuth and 60 degree elevation detection zone; robust data collection to locate firing source; and fast response time. The program will culminate with a demonstration of two prototype systems in a typical combat environment. Additionally, the program is investigating the feasibility of a variety of technologies to detect enemy shooters before the firing of a weapon. Promising technologies, such as the C-Sniper program, budgeted in this PE/Project, will be integrated with the Crosshairs capability to ensure maximum protection against enemy shooters.

(U) Program Plans:

FY 2007 Accomplishments:

- Identified and developed ultra-fast sensors and algorithms to detect and track multiple threats in near real time for static testing.
- Performed component testing and conducted detection and shooter localization demonstrations.

FY 2008 Plans:

- Analyze data and integrate sensors and response system for initial on the move capabilities.
- Perform on the move tests with the Vanguard vehicle.
- Enhance on the move sensor system capabilities to include decreasing false alarm and false tracks.
- Develop form factor and harden sensor system.
- Identify second overhead weapons station for integration on the Crosshairs vehicle.

FY 2009 Plans:

- Perform on the move testing of the integrated Crosshairs system against a variety of threats.
- Demonstrate the final system capability in live fire tests.
- Demonstrate networking capability between two Crosshairs sensor systems.

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	FY 2007	FY 2008	FY 2009
RPGNets	1.330	3.514	6.621

(U) The goal of the RPGNets program is to apply a rigorous scientific approach to the characterization of the interactions of special high-capability nets to dud, break, or otherwise disable rocket propelled grenades (RPGs). This program builds upon observed, but not well understood, capabilities of certain nets to disable RPGs in field tests and will provide models supplemented by high-precision experiments that characterize net performance and allow determination of optimal net systems for both ground vehicles and helicopters. The defined net systems will be tested in an extensive live fire program. If successful, they will be incorporated into defensive systems currently under development as a low-cost, low collateral damage RPG defense mechanism.

(U) Program Plans:

FY 2007 Accomplishments:

- Completed computer modeling of initial concept/net configurations.
- Conducted live fire testing of initial concept/net configurations.

FY 2008 Plans:

- Develop and validate models for fuse interaction, ogive crushing, and breaking of RPGs by nets.
- Design and fabricate instrumented RPG simulants for use in high-resolution experiments.

FY 2009 Plans:

- Based on model results, perform a series of high-resolution experiments in the Rapid Test Facility to extend and validate model performance.
- Define optimum net systems for RPG defeat and perform rigorous live fire field-testing.

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	FY 2007	FY 2008	FY 2009
Counter Improvised Explosives Laboratories (CIEL)	1.567	1.209	0.000

(U) Improvised explosives (IEs) are one of the most popular weapons used by terrorist groups. Over the past 20 years, IEs have become very common due to their easy preparation and the high availability of raw materials. Efficient methods for detecting and neutralizing/desensitizing sensitive explosives labs in an urban environment will minimize interference with troop operations and minimize collateral damages. The goal of the Counter Improvised Explosives Laboratories (CIEL) program is to develop the infrastructure and methodology for novel chemo-sensors that will identify labs that are building IEs to a very high degree of specificity and reliability; and develop the infrastructure for tools for safe handling of improvised explosives and their mixtures.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed a chemo-sensor that provides a clear and fast identification of the target explosive.
- Successful field tests performed to validate the methods for desensitizing and neutralizing explosives.

FY 2008 Plans:

- Identify a physical method that will neutralize/desensitize bulk explosive materials.
- Conduct feasibility demonstrations to neutralize/desensitize up to 1 Kg of the pure target explosive and mixtures.
- Optimize and demonstrate the sensor on pure target explosives and mixtures.

	FY 2007	FY 2008	FY 2009
Maneuver and Control on the Urban Battlefield	2.300	2.500	0.000

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

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(U) Program Plans:

FY 2007 Accomplishments:

– Initiated design and development of a rescue spreader end effector, energy storage and power delivery components for a portable, lightweight system.

FY 2008 Plans:

– Initiate integration of energy storage, power delivery, and end effector components into a single portable lightweight rescue spreader.

	FY 2007	FY 2008	FY 2009
Recognize Improvised Explosive Devices and Report (RIEDAR)	0.000	3.000	6.800

(U) The goal of the Recognize Improvised Explosive Devices and Report (RIEDAR) program is to develop and demonstrate a capability for standoff detection of various devices.

(U) Program Plans:

FY 2008 Plans:

– Demonstrate laser filamentation at 100 meters using low power lasers.

– Demonstrate operation of compact, tunable lasers from deep ultraviolet (UV) to near infrared (NIR).

FY 2009 Plans:

– Determine plume characteristics of explosive species in real meterological scenarios.

– Demonstrate compact, tunable lasers from deep UV to NIR in ruggedized structure.

	FY 2007	FY 2008	FY 2009
Lightweight Ceramic Armor (LCA)	0.000	4.500	6.500

(U) The Lightweight Ceramic Armor (LCA) program will leverage recent breakthroughs in novel ceramic fabrication processes developed in the Materials Processing Technology project to drive a dramatic performance shift in the tradeoff between weight and ballistic projectile protection

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of body armor. Currently fielded B4C body armor is heavy and limited in the diversity of shapes that may be molded. Its weight and bulk limit a soldier's agility and mobility, and its cost prohibits consideration of using it to protect vehicles. Recent breakthroughs in ceramics processing technology offers the opportunity for cost effective fabrication of molded shapes, the retention of nanostructured grains for significantly higher energy dissipation, a 50% reduction in weight for equal ballistic protection, and similar reduction in cost. The focus areas of the program will be the optimization of the material composition and nanostructure for maximum protection per unit weight and cost, and scale up of the fabrication technology to body armor size scale articles. The program will additionally investigate the potential for the development of dramatically improved ballistic armored headgear along these same lines.

(U) Program Plans:

FY 2008 Plans:

- Develop lightweight ceramic armor with high dynamic tensile stress to effectively dissipate shock waves.
- Investigate backing materials or materials systems for optimized energy dissipation characteristics when used in combination with this new class of ceramics.
- Develop improved processing of initial ceramic powder materials for improved ceramic performance, part yield, and yielded cost.
- Develop and model a scalable manufacturing process design for a pilot scale fabrication system capable of producing sufficient high performance ceramic material plates to support the end-manufacture of 1,000 systems per month.
- Validate an initial 15% reduction in weight for equal performance compared to currently fielded Enhanced Small Arms Protective Inserts (ESAPI) armor inserts.

FY 2009 Plans:

- Optimize integrated backing materials - ceramic armor materials systems for minimum weight at ESAPI ballistic performance.
- Evaluate the characteristics of an optimized LCA armor system optimized for minimum weight at ESAPI ballistic performance.
- Investigate the potential for significantly improved ballistic characteristics of meta-structured ceramic systems incorporating multiple materials layers in a monolithic plate.
- Validate a 30% reduction in weight for equal performance compared to currently fielded ESAPI armor inserts.
- Develop and evaluate initial concepts for ballistic headgear incorporating the LCA materials.
- Demonstrate key manufacturing steps at pilot scale throughput with consistent and reliable yielded ceramic part performance.

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	FY 2007	FY 2008	FY 2009
Small Combat Vehicle with Robotic Automation	0.000	2.500	3.000

(U) The Small Combat Vehicle with Robotic Automation program will evaluate and design small, survivable, highly mobile ground combat vehicles that have combat firepower equivalent to today's larger ground vehicles (e.g. M2/M3 Bradley) but in a highly deployable package of five ton to ten ton with a single crew person/operator on board (with the option for operation with no crew person in an unmanned configuration). Smaller vehicle weights enable effective deployability in helicopters or C-130 aircraft for vertical envelopment. This program seeks to achieve an optimal mix of manned and unmanned technologies in a small, well protected, highly deployable combat vehicle. By utilizing automation technologies in vehicle driving and vehicle payload systems (reconnaissance sensors and weapons), a single crew person in the combat vehicle can effectively drive and operate payloads concurrently at appropriate times while still providing high-level supervisory control over all systems. At mission critical times, the crew person can be removed and supervisory control can be given off-board from a separate controlling vehicle. The key technologies that enable a Small Combat Vehicle with Robotic Operation include sensor-based autonomous and semi-autonomous navigation, robust indirect driving (via combinations of cameras, perception-generated views of the terrain, or teleoperation), robust supervisory semi-autonomous control and teleoperation to allow vehicle operation from another vehicle, high density low-weight armor, aided target acquisition and targeting-based remote weapons stations, effective but minimalist warfighter-machine interfaces for crew person interaction with semi-automated driving and payload systems, and high performance vehicle mobility systems (suspensions and drivetrains).

(U) Program Plans:

FY 2008 Plans:

- Conduct initial studies and develop vehicle automation concepts.
- Conduct experiments and evaluations of candidate technologies.

FY 2009 Plans:

- Initiate preliminary designs.

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	FY 2007	FY 2008	FY 2009
Helicopter ALert and Threat Termination (HALTT)	0.000	3.030	7.000

(U) The Helicopter ALert and Threat Tracking (HALTT) program, an outgrowth of the Crosshairs program, will provide Army and Navy/Marine helicopters with a way to detect small arms and RPG attacks, improve their ability to respond, and provide affordable defeat of RPGs or other rockets. System effectiveness with emphasis on low false alarm rates is critical. The program goal is to successfully demonstrate protection of helicopters by automatic threat detection of small arms and RPGs, shooter localization, and threat mitigation/defeat.

(U) Program Plans:

FY 2008 Plans:

- Conduct component testing of the acoustic system during flight testing.
- Complete prototype system level integration with existing aircraft survivability equipment.
- Examine rocket threat detection and termination.

FY 2009 Plans:

- Conduct final acoustic component testing and demonstrate the prototype system.
- Develop HALTT system preliminary design and system integration plan.
- Perform live fire testing of individual subsystems.

	FY 2007	FY 2008	FY 2009
C-Sniper	0.000	6.712	11.600

(U) Based on promising results obtained under the Crosshairs program, the C-Sniper effort will develop the capability to detect and neutralize enemy snipers before they can engage U.S. Forces. The program will lead to the delivery of a field testable prototype suitable for experimentation as an integrated part of the DARPA Crosshairs system. The C-Sniper system will augment the Crosshairs system by identifying threats before they can fire. The enemy snipers may be operating both with, and without, telescopic sights, and other optical systems in highly cluttered urban environments. The C-Sniper system will operate day and night from a moving military vehicle and provide the operator with sufficient

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information to make a timely engagement decision. Once the decision is made, the C-Sniper will provide data and control to point and track the on-board weapon on the selected target. The final decision to fire the weapon will be left to the operator.

(U) Program Plans

FY 2008 Plans:

– Conduct feasibility studies of promising technologies to detect enemy shooters before the firing of a weapon.

FY 2009 Plans:

– Develop the key technologies (laser system, sensor head, and system processing designs).
– Develop the interfaces of the sensor system to integrate with Crosshairs.
– Conduct systems integration and test on stationary vehicle.
– Develop and incorporate system design enhancements required for a moving vehicle.
– Develop, deliver and demonstrate the operation of C-Sniper on moving vehicles.
– Demonstrate system capability to correctly detect optical systems in highly cluttered urban environment.

	FY 2007	FY 2008	FY 2009
Rocket Propelled Grenade (RPG) Pre-launch Detection and Cueing	0.000	0.000	3.000

(U) The Rocket Propelled Grenade (RPG) Pre-launch Detection and Cueing program will enable the development of an omni directional, visual, and vehicle mounted surveillance system for threat detection using cognitive swarm recognition technology to rapidly detect and identify the locations of attackers with RPGs before they are launched. During the first phase of the program, a system will be demonstrated capable of 360 degree coverage and detection rates of greater than 95%. Minimizing false alarms and false positives will be key, as will be true day/night operation and the simultaneous identification of up to five threats.

(U) Program Plans

FY 2009 Plans:

– Develop and mature detection and classification algorithms.
– Breadboard test of detection and classification algorithms.

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– Perform a system demonstration with stationary cameras.

	FY 2007	FY 2008	FY 2009
Micropower Engine	0.000	0.000	2.900

(U) The goal of the Micropower Engine program is to significantly improve the cost, weight, and overall capability of man-portable power systems by developing a small power system built around a fuel-breathing, hydrocarbon-fueled, recuperated, expander-cycle micro-scale turbine engine. This system can substitute for a standard battery, such as the BA5590, in military man-portable power applications. The availability of greater man-portable power increases the potential capability of man-portable electronic systems. It is well-established that power systems built around liquid-hydrocarbon-fueled micro-scale heat engines offer the potential of an order of magnitude (10x-50x) leap in energy density over chemical batteries. Such designs have not been reduced to practice because of the high rotational speed bearing limits at the microscale. The proposed engine is "fuel-breathing" rather than "air-breathing," using liquid hydrocarbon fuel, rather than air, as the working fluid of its thermodynamic cycle thus enabling compression at much lower rotational speeds.

(U) Program Plans:
FY 2009 Plans:
– Conduct a trade study determining engine performance through various size ranges.
– Demonstrate novel compressor/injector at mesoscale.
– Design a microscale engine to the preliminary level.

	FY 2007	FY 2008	FY 2009
Defeat of Explosively Formed Projectiles (DEFP)	0.000	0.000	3.500

(U) The objective of the Defeat of Explosively formed Projectiles (DEFP) program is to develop technologies to counter Explosively Formed Projectiles (EFPs). EFPs have become the "threat of the future" for insurgent forces as they can penetrate all of today's armored vehicles including tanks. Since EFPs penetrate largely by virtue of their momentum, they are not susceptible to simple forms of reactive armor. New

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approaches to be investigated include a new generation of "smart armor" that combines sub-millisecond sensing and processing with directable explosively driven counter-EFP devices. This armor will reduce, re-direct, and disperse the penetrating elements of the EFP to a point such that the base armor of a Bradley Fighting Vehicle would not be perforated. This program seeks to provide this capability at an added weight of less than 40 lbs per square foot.

(U) Program Plans:
FY 2009 Plans:
- Demonstrate sensing, processing, and ballistic components.
- Perform component live fire tests.

	FY 2007	FY 2008	FY 2009
Silversword	0.000	0.000	4.100

(U) The Silversword program will develop power-source and radio frequency (RF) component technologies for multi-pulse, ultra-compact, wideband, gigawatt microwave sources.

(U) Program Plans:
FY 2009 Plans:
- Employ RF munitions at gigawatt power levels to irradiate electronic systems.
- Configure a Blumlein-driven source to defeat the electronic front ends of remotely-triggered devices and to investigate the susceptibility of military, commercial, and consumer electronics.

	FY 2007	FY 2008	FY 2009
Army Hypersonics Advanced Technology	2.000	0.000	0.000

(U) Established Hypersonics Advanced Technology initiatives.

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	FY 2007	FY 2008	FY 2009
Extreme Light Sources for Defense Applications	1.440	0.000	0.000

(U) Researched extreme light sources.

	FY 2007	FY 2008	FY 2009
Optical Sensor System	1.000	0.800	0.000

(U) Researched optical sensors.

	FY 2007	FY 2008	FY 2009
Research on a molecular approach to HazMat Decontamination	1.000	0.000	0.000

(U) Researched HazMat Decontamination on a molecular approach .

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Advanced Tactical Technology TT-06	103.715	113.550	114.421	84.028	59.820	59.820	60.314

(U) Mission Description:

(U) This project focuses on four 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; and d) new approaches for training and mission rehearsal in the tactical/urban environment. Additionally, this project will develop new tactical systems for enhanced air vehicle survivability, precision optics, electronic warfare, and advanced air breathing weapons.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Super High Efficiency Diode Sources (SHEDS)	4.000	4.000	4.000

(U) The goal of the Super High Efficiency Diode Sources (SHEDS) program is to develop laser diodes that are 80% efficient in converting electrical power to optical power. These will be used for supplying the optical power to ytterbium (Yb) and neodymium (Nd) solid state lasers operating near 1060 nanometers (nm). Such high efficiency laser pumps for these solid state lasers will lead to dramatic reductions in the size and weight of 100 kW class diode pumped solid state lasers. The goal of the SHEDS Plus Program is to retain high wall-plug efficiency of over 70% while producing diode bars with 200 W/bar-cm, lifetimes of greater than 1000 hours (hrs.). In addition, SHEDS Plus plans allows operation at the increased inlet water cooling temperatures exceeding 55°C which provides for 2 or 3-fold higher thermal management efficiency in many applications.

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated single edge-emitting laser diodes operating at record-high efficiency.
- Demonstrated a stack of edge-emitting laser diode bars operating at high-power and record-high efficiency.
- Demonstrated an array of vertical-external-cavity surface-emitting laser (VCSEL) laser diodes operating at record efficiency.

FY 2008 Plans:

- Demonstrate an array of VCSEL laser diodes operating at high-power density and high efficiency.
- Demonstrate a quantum dot laser diode bar operating at record-high efficiency.
- Establish methods to increase diode power output by increasing laser cavity length without sacrificing efficiency.
- Demonstrate improvements in diode lifetime through suppression of filamentation and instabilities.
- Enable diode operation at increased inlet water cooling temperatures.

FY 2009 Plans:

- Demonstrate a quantum dot laser diode bar operating at high-power and record-high efficiency.
- Demonstrate diode bar lifetime greater than 100 hours.
- Demonstrate power per bar above 85 W/Bar.
- Increase working coolant temperature beyond 35°C.

	FY 2007	FY 2008	FY 2009
High Energy Liquid Laser Area Defense System (HELLADS)	29.000	38.500	40.608

(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 <5 kg/kW, HELLADS will enable high-energy lasers (HELs) to be integrated onto tactical aircraft and will significantly increase engagement ranges compared to ground-based systems. The HELLADS program has completed the design and demonstration of a revolutionary subscale high-energy laser that supports the goal of a lightweight and compact high energy laser weapon system. An objective unit cell laser module with integrated power and thermal management is being designed and fabricated and will demonstrate an output power of >34 kW. A test cell that represents one-half of the unit cell laser has been fabricated and used to characterize system losses and diode performance and reliability. The test cell is being expanded to a unit

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cell. Based on the results of the unit cell demonstration, additional laser modules will be fabricated to produce a 150 kW laser that will be demonstrated in a laboratory environment. The 150 kW laser will then be integrated with an existing beam control capability to produce a laser weapon system demonstrator. The capability to shoot down tactical targets such as surface-to-air missiles and rockets will be demonstrated.

(U) Program Plans:

FY 2007 Accomplishments:

- Designed and fabricated a test cell.
- Completed diode stack life testing of both protected and unprotected diodes in HELLADS environment.
- Completed characterization of laser losses.
- Initiated development of the laser weapon system demonstrator components.

FY 2008 Plans:

- Fabricate a test head and characterize the optical performance of the unit cell.
- Complete preliminary design of a 150 kW laser weapon system demonstrator.

FY 2009 Plans:

- Complete a unit cell laser module with integrated power and thermal management subsystems and demonstrate power, beam quality, run-time, weight, and volume.
- Complete detailed design of a 150 kW laser weapon system demonstrator.

	FY 2007	FY 2008	FY 2009
Aero-Adaptive/Aero-Optic Beam Control (ABC)*	0.000	4.000	5.000

*Previously part of High Energy Liquid Laser Area Defense System.

(U) The goal of the Aero-Adaptive/Aero-Optic Beam Control (ABC) program is to improve the performance of high energy lasers on tactical aircraft against targets in the aft field of regard. In order to achieve high off-boresight targeting capability, current optical turret designs protrude into the flow. This causes severe aero-optic distortions in the aft field of regard due to turbulence in the wake and the unsteady shock movement over the aperture. These distortions decrease the power flux on target (the measure of lethality for a directed energy system) and limit the directed energy system to targets in the forward field of regard. This program will optimize flow control strategies for pointing angles in the aft field of

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regard. The program will also explore the ability of the flow control system to be synchronized with adaptive optics. This effort will initially focus on wind tunnel testing to prove the feasibility of steady and periodic flow control techniques to reduce or regularize the large scale turbulent structures surrounding an optical turret. These tests will culminate in a hardware-in-the-loop demonstration with an adaptive optics system. Following successful wind tunnel demonstrations, a preliminary design of a flight test turret incorporating flow control will be undertaken.

(U) Program Plans:

FY 2008 Plans:

- Initiate trade studies and computational fluid dynamics (CFD) analyses.
- Characterize turret aero-optical performance with CFD analysis and small-scale wind tunnel testing.
- Downselect to preferred turret and flow control configuration.

FY 2009 Plans:

- Use CFD to optimize blowing slot configuration.
- Assess wavefront measurements for a range of pointing angles.
- Downselect flow control actuation technique.

	FY 2007	FY 2008	FY 2009
High Performance Algorithm Development	16.924	15.931	10.200

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

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(U) Program Plans:

FY 2007 Accomplishments:

- Strategy developed for automatic generation of low power, minimal area, fast convolution algorithms that are developed in less than 1/10th the time of hand tuned engineering experts with better performance.
- Transitioned methods to industry for the generation of fast Fourier Transform codes.
- Implemented strategy for sparse fast multi-pole methods that lead to the co-design of optimal codes and a board based upon field programmable gate arrays.
- Demonstrated superiority of time reversal methods compared to conventional matched filtering processing for situations involving multipath clutter.
- Developed principled multi-scale graph theoretical methods that decompose non-linear systems into smaller systems.
- Demonstrated methods that reduce the number of experiments required to map a non-linear dynamical system.
- Demonstrated new methods to design dynamics of mobile sensors to support surveillance in the presence of sensor and platform uncertainties.
- Discovered high-dimensional patterns in the statistics of natural images using methodology developed in the topological data analysis program.
- Developed novel, non-linear compression schemes based on high-dimensional topological patterns.
- Demonstrated application of computational topology to information representation in the brain.
- Constructed novel, non-linear, non-invasive medical statistics to assist doctors in understanding risks when assessing patients in intensive and critical care situations.
- Developed a software tool to analyze algorithms for representation based on clustering.
- Established a precise correspondence between theoretical mathematics and quantum physics.

FY 2008 Plans:

- Extend methods from kernels to end-to-end applications including JPEG2000, Viterbi coding, and Synthetic Aperture Radar (SAR) processing.
- Extend time reversal theory to form complete images of targets in multipath environments.
- Test hypothesis that multipath scattering will enable portions of the target that are not illuminated to be imaged.
- Develop test range facility and clutter environment to support experimentation at Ka band.

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- Extend methods to cope with nonlinear systems with dimensionality greater than 10,000 degrees of freedom. Accelerate the methods to achieve 100x performance over particle filtering and Monte Carlo sampling. Demonstrate the method in 2.5 dimensions with over 10,000 degrees of freedom.
- Develop novel clustering algorithms that address stochasticity and uncertainty.
- Expand software tool capability and functionality to address complex datasets of military importance.
- Inject novel mathematical tools into quantum physics calculations.
- Develop new mathematical approaches to approximate infinite calculations by polynomial ones.
- Demonstrate new mathematical results in communications networks and number theory based on novel geometric methods.
- Demonstrate improved performance of geometrically inspired algorithms for communication networks, tomographic inversion, and numerical solutions of partial differential equations.

FY 2009 Plans:

- Demonstrate using the Discovery and Exploitation of Structure in Algorithms tools that non-expert users can design end-to-end systems for JPEG2000, Viterbi coding, and SAR that are designed in $1/10^{th}$ the time of expert designers and that have equivalent performance.
- Extend DESA tool suite to other common signal processing and image formation algorithms.
- Extend time reversal methods to acoustic channels and increase the computational speed of the Green's function by 100.
- Apply time reversal methods to detect and image targets in clutter that can not detected by conventional processing.
- Extract images of targets in clutter and export the target chits to an automatic target recognition and compare performance of the automatic target recognition system against and image of the same target in the clear.
- Apply the Robust Uncertainty Management developed methods to a DARPA specified cooperative surveillance problem in which the sensors have stochastic performance, probabilistic data links, and requirements for multiple looks.
- Use topological tools previously developed to analyze higher-order datasets in biology, sensing, neuroscience, military, and community networks.
- Establish and exploit new relations between topology, number theory, and symmetry groups of fundamental particles.
- Tie advances in pure mathematics to defense applications in cryptography, quantum sciences, materials, and nano-level structures.
- Develop a quantitative methodology in the area of information propagation and understanding for the military and coalition environment, relying on observations from neuroscience, cognitive science and social networking.
- Develop and test new algorithms in which geometry is the starting point for design.

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– Demonstrate capabilities on test bed problems aligned with DoD mission that are not certifiably attainable by approaches currently in use.

	FY 2007	FY 2008	FY 2009
Integrated Sensing and Processing	10.000	4.373	7.500

(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, and novel approaches to multiplexed hyper-spectral chemical/biochemical sensing systems.

(U) Program Plans:

FY 2007 Accomplishments:

– Demonstrated that closed loop adaptive processing led to a 7x reduction in the number of pixels sensed in both variable acuity and hyper-spectral scenarios relative to conventional processing.
– Developed self-localizing, power aware, 1 bit processing, non-myopic scheduling for motes and demonstrated the ability of the mote field to detect and track slow moving targets with 10x power reduction relative to existing methods.
– Developed, tested, and verified the performance of a new analog imaging chip for embedded low-power applications such as missile seekers.
– Developed new representations for scalar fields on the sphere which lead to file sizes that are 100x smaller than conventional representations with no loss of fidelity in applications.
– Developed new contrast and illumination-independent representations for images that lead to automated registration (better than 0.5 pixels) and mosaicking at 2 hertz (Hz).

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- Created new file structure to support streaming video for disadvantaged users at 100x compression with no impact on visual quality developed.
- Developed a robust target enumeration theory and corresponding algorithms for distributed dynamical sensor networks.
- Developed novel pursuit and capture criteria for multiple pursuers that works in non-convex domains, using comparison geometry.
- Determined the composition of the chemical specifications.

FY 2008 Plans:

- Develop theory of compressed sensing for small targets using imaging systems.
- Demonstrate in simulation detection and track of small targets comparable to baseline detect and track with on the order of N (O(N)) fewer measurements.
- Evaluation of the FY 07 Geospatial Representation and Analysis (GEO) products by National Geospatial-Intelligence Agency (NGA).
- Extend the registration methods to 0.1 pixel registration error and operation at 15 Hz.
- Extract three dimensional structure from video at 3 Hz.
- Develop meshless wavelet basis and topological representations that yield 50x improvement over conventional representations with less than 1% distortion in end user applications.
- Expand FY 07 accomplishments by addressing stochasticity and uncertainty in DoD sensing applications.
- Extend theory of configuration spaces to information spaces for network systems and sensing applications.
- Determine the material requirements with regard to several dimensions of operation and use.

FY 2009 Plans:

- Extend theory of compressed sensing for small targets using imaging systems to determine sparse bases and provide design for a next generation sensor.
- Demonstrate detection and tracking of small targets comparable to baseline detect and track with significantly fewer measurements.
- Transition FY 08 products to NGA.
- Extend registration methods to 0.1 pixel registration error and operation at 30 Hz.
- Extract three-dimensional structure from video at 30 Hz.
- Develop meshless wavelet basis and topological representations that yield 100x improvement over conventional representations with less than 0.5% distortion in end user applications.
- Demonstrate that Sensor Topology for Minimal Planning provides coverage, encirclement, and pursuit capabilities in a real DoD distributed sensing scenario that are not certifiably attainable by approaches currently in use.

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	FY 2007	FY 2008	FY 2009
Training Superiority	8.718	9.791	13.071

(U) The Training Superiority program will change the paradigm for military training by creating new approaches to increase technical competence. 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, this thrust will scale-up new digital tutor methodologies, deliver these to a large cohort of warfighters, and demonstrate a convincing benefit compared to standard training in an operational environment.

(U) Program Plans:

FY 2007 Accomplishments:

- Transitioned user-authorable PC-based small unit training tool, *DARWARS Ambush!*, to the Army (>20,000 Soldiers, Marines and Airmen trained this year).
- Developed new scenarios to demonstrate the potential for training non-kinetic operations with user-authorable PC simulation.
- Completed transition of Tactical Language and Culture Training to Special Forces and the U.S. Marine Corps.
- Competed Tactical Pashto language and cultural trainer.
- Transitioned multi-user training architecture to the Joint Forces Command and the OSD's Advanced Distributed Learning Initiative program.
- Initiated Education Dominance program, in cooperation with the Navy, to develop digital tutors that teach better than the best classroom tutors.
- Delivered an A-10C part task trainer to the Air Force which is currently being used to train pilots at Nellis AFB.
- Delivered an Electronic Weapons Officer training capability to the Air Force which is currently being used to train students at Randolph AFB.

FY 2008 Plans:

- Create compelling, digital tutor training for Navy information technicians that trains as well as the best human tutors.
- Design experiment to demonstrate the effectiveness of those so trained in a fleet exercise: the Infantry Warrior Simulation Cup.

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FY 2009 Plans:
- Demonstrate 40-hour Digital Tutor, teaching one week of content, in a production software configuration.
- Port three weeks of content from a human-tutored course to the Digital Tutor and test in a laboratory setting.
- Conduct and evaluate the first Information Warfare Cup (IWARS Cup) using the human-tutored team.
- Enable the presentation of synthetic opposition forces (OPFOR) within the real world training environment.

	FY 2007	FY 2008	FY 2009
RealWorld*	0.000	9.200	12.125

*Previously funded under Training Superiority.

(U) The RealWorld program exploits technical innovation and integration to provide any U.S. warfighter with the ability to open a laptop computer and rehearse a specific mission in the relevant geo-specific terrain, with realistic physics. Because the system will be scalable and distributed, warfighters can practice by themselves, in small groups, or with as many other warfighters as needed for the mission over a local or distributed network, and across all relevant platforms (dismounts, vehicles, helicopters, fast movers). Most important is the understanding that RealWorld is not a simulation; it is a simulation builder with applications across the spectrum of modern kinetic and non-kinetic warfare. The program is building tools that allow warfighters to rapidly and easily build their own missions though the introduction of new methodology for building simulation software. These methodologies and adherence to a highly modular approach will cause a fundamental paradigm shift in the acquisition, as well as the construction, of DoD modeling and simulation products.

(U) Program Plans:

FY 2008 Plans:
- Demonstrate automated geo-specific terrain from digital terrain elevation data.
- Demonstrate scalability to 250 live network participants running on a single server, thus surpassing current DoD multi-player capacity.
- Demonstrate integration of Newtonian physics.
- Apply RealWorld simulation builder to digital cockpit training.
- Transition RealWorld Air component to Air Force as the universal trainer for A-10C.

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- Apply RealWorld simulation builder to electronic warfare applications. Transition RealWorld Electronic Weapons Officer component to Air Force.
- Scale to 500 entities.
- Demonstrate 3-D positional audio, multi-channel audio and physical modeling of communications jamming effects including multi-spectrum and frequency jamming.
- Implement an artificial intelligence (AI) Abstraction layer allowing the future integration of disparate AI systems.
- Develop a rendering solution capable of supporting hardware that can render images ranging from 1080p high definition to PlayStation Portable quality.
- Ingest 1 sq. km. of government terrain data into a physics based 3-D real-time software environment in thirty minutes.
- Ingest 360 sq. km. of government terrain data into a physics based 3-D real-time software environment in four hours.
- Create up to 38,000 sq. km of terrain data for air specific missions, anywhere in the world, in one hour.
- Automatically generate the interior (including furniture and stairways) and exterior of a geo-typical building of any size or footprint in under 5 minutes that includes building material types by zip code.
- Initiate development of a universal medic simulation builder.
- Demonstrate utility as a trainer for at least one SOCOM application.

FY 2009 Plans:

- Scale to 1000 entities.
- Demonstrate dynamic path finding such that entities will be able to maneuver in a terrain deformed geo-specific area.
- Integrate meteorological capability so real-time weather can be imported into training and rehearsal scenarios.
- Demonstrate integration of data from Google Earth.
- Integrate a full Newtonian physics modeling engine in a real-time 3-D engine in both a hardware enhanced and software only modality.
- Transform pictures taken by a cell phone camera into a 3-D model capable of being ingested by a real-time 3-D engine with an accuracy of one or less.
- Transform a laser imaging detection and ranging (LIDAR) data collection set into a 3-D model (using topology graph analysis and parametric model fitting) capable of being utilized by a real-time 3-D engine.
- Ingest up to 1 sp. mile of LIDAR terrain data and render 3-D models in under one hour.
- Transition to military customers.

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	FY 2007	FY 2008	FY 2009
Air Laser	4.739	1.000	2.000

(U) The Air Laser program investigated the potential for a high energy laser concept based on direct diode pumping of liquid nitrogen. The Air Laser concept sought to combine the advantages of chemical and solid state lasers while minimizing the disadvantages. It used liquid nitrogen as the gain medium and as the diode array coolant, resulting in the reduction of a separate thermal control system. Use of efficient, high-power diode pump sources resulted in a compact device much smaller than either chemical or solid state lasers, and its pulse length was variable from continuous to sub-picosecond, allowing flexibility in weapons effects.

(U) Program Plans:

FY 2007 Accomplishments:

- Performed system/utility analyses.
- Conducted laboratory experiments to characterize high-power cryogenic pump lasers.

FY 2008 Plans:

- Develop and demonstrate a 1 kW output power laser design.

FY 2009 Plans:

- Develop a 100 kW laser design.

	FY 2007	FY 2008	FY 2009
Efficient Mid-Wave Infrared Lasers (EMIL)	5.394	8.700	7.900

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

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

(U) Program Plans:

FY 2007 Accomplishments:

- Improved wall plug efficiency by 13%.
- Improved continuous wave output power by 22%.
- Observed a 40% reduction in waveguide loss.

FY 2008 Plans:

- Demonstrate the projected efficiency, power and beam quality levels from single-mode Indium Phosphide (InP)-based QCL emitters.
- Demonstrate device mounting modeling and fabrication for reduced electrical and thermal resistance.
- Test final device integration.

FY 2009 Plans:

- Scale the power, in a parallel development, of the efficient individual QCL sources developed previously.
- Demonstrate epitaxial growth and preliminary characterization of final structures.

	FY 2007	FY 2008	FY 2009
Sonic Projector	2.500	5.437	1.000

(U) The goal of the Sonic Projector program is to provide the services with a method of surreptitious audio communication at distances over 1 km. Sonic Projector technology is based on the non-linear interaction of sound in air translating an ultrasonic signal into audible sound. The Sonic Projector will be designed to be a man-deployable system, using high-power acoustic transducer technology and signal processing

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algorithms which result in no, or unintelligible, sound everywhere but at the intended target. The Sonic Projector system could be used to conceal communications for special operations forces and hostage rescue missions, and to disrupt enemy activities.

(U) Program Plans:

FY 2007 Accomplishments:

– Completed initial feasibility studies.

FY 2008 Plans:

– Conduct design analysis for high-power ultrasonic transducers, and precision beam control and focus for target tracking.

– Create concept of operations and conduct military utility analyses.

FY 2009 Plans:

– Initial lab demonstrations of long-range sonic projector system.

	FY 2007	FY 2008	FY 2009
Revolution in Fiber Lasers (RIFL)	0.000	1.500	2.000

(U) The goal of the Revolution in Fiber Lasers (RIFL) program is to develop multi-kilowatt, single-mode, narrow line-width fiber laser amplifiers using diffraction-limited diode pump arrays to achieve the requisite power and coherence for future multi-kilowatt directed energy architectures. The excellent beam quality of the diffraction-limited diodes allows for a tenfold reduction in cladding diameter. The faster, more efficient coupling from cladding to core will result in a 10x shortening of the required fiber length to avoid nonlinearities and create narrow line-width beams. Furthermore, the reduction in cladding diameter will provide a 70x increase in the heat removal rate from the core, increasing the thermal fiber laser power scaling limit to 10 kW. This program will construct stable 100 W, 10-emitter bars (10 W/emitter) and assemble a 15-bar fiber tree capable of producing 1.5 kW of diffraction-limited diode laser pump power per module. These modules will then be used to pump a multi-kilowatt fiber laser amplifier.

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(U) Program Plans:

FY 2008 Plans:

- Demonstrate a 1 kW fiber amplifier with array output combining characteristics (i.e., spectral, polarization and spatial characteristics) that support the controlled combining of outputs from arrays of apertures.
- Demonstrate the process for combining the outputs 10 W fiber amplifiers.
- Demonstrate a 30% efficient diode based pump source that drives 2 kW on 400 Om fiber.
- Demonstrate a >2 kW output power F >15% efficient fiber amplifier with many output combining characteristics.
- Demonstrate controlled combining of 10 W fiber amplifiers.

FY 2009 Plans:

- Demonstrate a 40% efficient diode based pump source that drives 3 kW on 400 Om fiber.
- Demonstrate a >4 kW output power, 30% efficient fiber amplifier with array output combining characteristics.

	FY 2007	FY 2008	FY 2009
Coherently Combined High-Power Single-Mode Emitters (COCHISE)	0.000	6.200	6.017

(U) Building upon the preliminary success of the Super High Efficiency Diode Sources (SHEDS) program, the Coherently Combined High-Power Single-Mode Emitters (COCHISE) program will develop four new, breakthrough technologies that will result in improved diode bar lifetime and beam quality. Ultimately, these technologies will also lead to coherent combination of individual emitters in laser diode bars and arrays. Coherent combination of laser diode arrays would provide high power laser architectures that are up to 3x more efficient than existing diode-pumped solid-state laser technology, while improving beam quality and increasing far-field, on-axis intensity.

(U) Program Plans:

FY 2008 Plans:

- Demonstrate a diode bar pre-screening technology based on spectral measurements made on each emitter that can detect $<1^{o}C$ temperature changes among these emitters simultaneously and that can detect packaging defects and other manufacturing defects (High Energy Liquid Laser Area Defense System (HELLADS) diode bars).

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- Correlate electrical fault mode detection based on voltage drops at the diode terminals with optical fault mode detection based on spectral splitting in diode or bar emission (>70% correlation).
- Demonstrate that fault mode frequency as detected electrically at the diode bar terminals correlates with diode bar lifetime – use as an additional diode bar pre-screening technology.
- Demonstrate that SHEDS laser diode bar lifetime can be extended beyond 500 hrs. at full efficiency and power with fault mode protection.
- Demonstrate phase control of individual slab-coupled optical waveguide lasers (SCOWL) emitters to >0.1 waves with a compact diode driver containing integrated fault-mode, protection and the ability to cut current to the SCOWL diode in <2 μsec.
- Use fault-mode protection to extend HELLADS diode bar lifetime to >500 hrs. at a cooling water temperature of 55°C.
- Extend HELLADS diode bar lifetime and efficiency fivefold at cooling water temperatures of 65°C and 75°C with fault mode protection.

FY 2009 Plans:

- Demonstrate a stable synthetic bar of 10 SCOWL diodes at 10 W with 1.4x diffraction limited beam quality.
- Demonstrate that a synthetic bar of 10 SCOWL diodes, each powered independently with an intelligent, fault-mode-protected, Complimentary Metal-Oxide Semiconductor-based driver, can be operated coherently in a Talbot cavity and/or other optical cavity geometries that promote self-assembly of a coherent cavity super-mode.

	FY 2007	FY 2008	FY 2009
Architecture for Diode High Energy Laser Systems (ADHELS)	7.000	4.918	0.000

(U) The Architecture for Diode High Energy Laser Systems (ADHELS) program will develop all-solid-state laser diode drivers with integrated fault mode protection that will decrease the size and weight of these laser systems by a factor of four (by allowing the laser diode array to operate at elevated temperatures), increase the diode array lifetime tenfold, and decrease lifecycle costs fivefold. These improvements will be attained for diode laser arrays operating in the infrared, visible and ultra-violet regions of the spectrum. By allowing operation at higher temperatures, these new drivers will allow broader tuning of the laser light which is crucial to the detection of both chemical and biological agents with high signal-to-noise and low probability-of-false-alarm. These new diode laser drivers will utilize feedback control systems which detect

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electrical and optical filamentation within the laser diode and laser diode bars, and then interrupt power to the laser diode system before thermal instabilities can lead to accelerated diode aging and premature diode failure.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated all electric coherent power combining of two lasers diodes.
- Demonstrated a surface-emitting distributed feedback (SE-DFB) laser diode operating at high power and high efficiency.

FY 2008 Plans:

- Demonstrate a kilowatt-class high-power laser with high-efficiency and good beam quality.
- Demonstrate a SE-DFB laser diode operating at high-power, high-efficiency and good beam quality.
- Demonstrate volume Bragg gratings suitable for high-power beam combining and good spectral efficiency.
- Demonstrate a kilowatt-class high-power laser with record-high efficiency and excellent beam quality.
- Demonstrate a SE-DFB laser diode operating at high-power, record-high efficiency and excellent beam quality.
- Demonstrate volume Bragg gratings suitable for high-power beam combining and high-spectral efficiency.

	FY 2007	FY 2008	FY 2009
Laser Star	4.000	0.000	0.000

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

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tilt. Laser Star explored approaches to overcome these shortfalls including advanced multi-conjugate adaptive optics as well as nonlinear techniques.

(U) Program Plans:
FY 2007 Accomplishments:
- Completed concept design.
- Conducted experiment and analyzed results for integration with atmospheric compensation programs.

	FY 2007	FY 2008	FY 2009
GORGON - High Power Mid-IR Laser	0.000	0.000	3.000

(U) The GORGON – High Power Mid-IR Laser program will develop and integrate advanced laser and detector technologies to provide proactive IRCM capabilities for a variety of airborne platforms as required by the Multi-function Electro-optical Defense of U.S. Aircraft (MEDUSA) program.

(U) Program Plans:
FY 2009 Plans:
- Perform search/interrogate function based on a vertical-external-cavity surface emitting laser (VECSEL) technology.
- Utilize the laser based on double-clad erbium (Er)-doped zirconium barium lanthanide sodium fluoride (ZBLAN) fiber pumped with λ=975 nm laser bars to carry out the search/interrogate function.

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	FY 2007	FY 2008	FY 2009
Coherent Communications, Imaging and Targeting (CCIT)	3.000	0.000	0.000

(U) The Coherent Communications, Imaging and Targeting (CCIT) program pursued new capabilities for secure communication up-links, and aberration free 3-dimensional imaging and targeting at very long ranges. Innovative design concepts for MEMs based Spatial Light Modulators, and system integration of photonics and high-speed electronics were also explored.

(U) Program Plans:
FY 2007 Accomplishments:
- Completed 64 x 64 device with individually “wired” test pixels.

	FY 2007	FY 2008	FY 2009
Rapid Checkpoint Screening	3.740	0.000	0.000

(U) The Rapid Checkpoint Screening program developed and demonstrated 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:
FY 2007 Accomplishments:
- Completed transition of the research programs and findings to the Department of Homeland Security.

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	FY 2007	FY 2008	FY 2009
High Power Fiber Lasers	4.700	0.000	0.000

(U) The High Power Fiber Lasers program developed and demonstrated single mode, single polarization fiber lasers with output powers greater than one kilowatt from a single aperture. High power fiber lasers have the potential to 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, and rockets.

(U) Program Plans:
FY 2007 Accomplishments:
- Demonstrated greater than 100 watt single mode polarized output power from a single large mode-field area fiber.
- Demonstrated greater than 1 kilowatt output power from a single large mode-field area fiber.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Aeronautics Technology TT-07	58.505	52.756	58.158	64.856	67.486	68.105	70.086

(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 2007	FY 2008	FY 2009
Helicopter Quieting	8.872	9.900	7.000

(U) Studies and analysis of military helicopter operations have shown that the survivability and lethality of U.S. helicopters can be increased by reducing their acoustic signature, which will make them more difficult to detect, track, and engage. The goal of the Helicopter Quieting Program (HQP) is to identify, develop and demonstrate advanced rotor technologies that can dramatically improve the survivability of military rotor systems, with minimal negative impact on performance, affordability, availability and suitability. A critical element toward this goal is to create and demonstrate a physics-based design toolset that enables analytical design of novel rotor systems and rotorcraft for reduced acoustic susceptibility (detection and recognition) by the human threat.

(U) Current rotor development is very costly, involving a time-consuming iterative, trial and error cycle of analysis and model wind tunnel tests, or occasionally, a faster but much riskier analysis path directly to full-scale wind tunnel/flight test. Additionally, the primary limitation of existing computational models is their inability to accurately predict the pressure distribution on a rotor blade and in the flowfield away from the blade. Novel and creative concepts and ideas are being employed in this program for accurate aerodynamic analysis of helicopter rotor airloading, flowfield, and wakes using high-end computational fluid dynamics techniques. The program will investigate multiple advanced, low-noise rotor

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concepts for application to fielded military rotorcraft for a significant reduction in low-frequency in-plane signatures. The most promising concepts will be taken to test, culminating in full scale flight experiment of advanced rotors to confirm acoustic signature reduction and evaluate survivability improvement in an operational environment.

(U) This program will also undertake the development of propagation and perception modeling for rotorcraft acoustic signatures within state-of-the-art visualization architectures. Multiple advanced human perception and cueing models will be developed as a part of the integrated acoustic design and analysis environment. The ability of the toolset to accurately characterize the differences in these factors will support design decisions for advanced, low noise rotors and rotorcraft.

(U) Program Plans:

FY 2007 Accomplishments:

– Developed high-fidelity, physics-based rotor acoustic predictive tools, and demonstrated correlation for conventional rotors.

FY 2008 Plans:

– Validate high-fidelity, physics-based rotor acoustic predictive tools for rotors that exhibit complex aerodynamic phenomena atypical of conventional, fielded rotorcraft.
– Identify acoustic design criteria for new rotor system designs based on operational scenarios.

FY 2009 Plans:

– Develop and demonstrate advanced rotor system designs that incorporate reductions in low-frequency, in-plane signatures for increased survivability without significant impact to flight performance.

	FY 2007	FY 2008	FY 2009
Nano-Flapping Air Vehicles	6.956	9.726	8.000

(U) The goal of this program is to develop flapping and rotary air vehicle technology that results in a bio-inspired flapping and rotary air vehicle with less than two inch wingspan and gross take-off weight of approximately ten grams or less. Operations in the urban terrain require sensors that can navigate in difficult terrain and be inserted without being detected. Small air vehicles capable of navigating interior domains without GPS would enable autonomous prosecution of a number of high risk missions that are currently performed by warfighters. Key enabling technologies include, flapping and rotary wing aerodynamics, kinematics and flight dynamics, lightweight aeroelastically tailored wing structures,

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miniature navigation systems, micro-propulsion systems, small payloads, and the ability to perch like a bird. This effort will also examine novel materials that can be used to develop integrated wing structures, which change composition to achieve multiple expressions. The program would result in the use of vehicles, which could be camouflaged, or blend into the surrounding landscape, enabling in-theater disposal and prevention of mission detection/compromise.

(U) Program Plans:

FY 2007 Accomplishments:

– Designed and tested first phase flapping and rotary wing geometry and mechanism.
– Investigated and proved feasibility of a high performance airfoil at low Reynolds number.

FY 2008 Plans:

– Demonstrate robust flapping and rotary mechanisms that produce 10 grams of lift, integrate wing design with air vehicle, and reliable multifunctional wing manufacturing principles.
– Develop novel communication and navigation schemes that allow vehicle control both outdoors and indoors.

FY 2009 Plans:

– Fabricate and assemble flight demonstration vehicles and perform flight tests to evaluate flight performance, navigation capability, and system ability to carry out mission.

	FY 2007	FY 2008	FY 2009
Battlefield Helicopter Emulator (BHE)	6.469	8.750	9.321

(U) The goal of the Battlefield Helicopter Emulator (BHE) is to develop a system capable of emulating rotorcraft signatures, compatible with installation as a payload on a small UAV. The system will provide helicopter signature emulation of a variety of battlefield helicopters. BHE could be used for mine clearing/route determination as well as escort missions. An operational system could draw fire from ground based adversaries, and relay the information back to the operator for off-board location and prosecution. The system's capability to defeat threats with an off-board system offers the opportunity to protect a large number of military aircraft assets and crews over long periods without aircraft performance impact. The reduced acoustic perception distance enabled by the BHE system can reduce the risk to Army and SOCOM helicopters

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from ground fire, small arms, rocket-propelled grenades (RPGs), man-portable air defense systems (MANPADS), and anti-helicopter mines (AHMs).

(U) Program Plans:

FY 2007 Accomplishments:

- Developed and tested techniques to demonstrate technological feasibility.
- Developed initial concept of operations.

FY 2008 Plans:

- Identify technical approaches for adequately emulating critical signatures.
- Characterize signatures of battlefield helicopters.
- Develop concepts to emulate battlefield helicopter signatures.
- Develop and test emulator system to demonstrate technological feasibility in a laboratory environment.
- Development of analytical constructive simulation capability to assess performance of proposed technologies and mature key system performance criteria.

FY 2009 Plans:

- Select and integrate emulator systems with UAV platform.
- Conduct field tests to determine system capability and effectiveness against potential threats.

	FY 2007	FY 2008	FY 2009
Distributed Embedded Propulsion	0.000	4.200	5.000

(U) The Distributed Embedded Propulsion program will explore fully integrated engine/wing designs to take maximum advantage of a fully coupled engine/wing system. This concept will utilize multiple small engines to provide the thrust for the aircraft, and to allow the engines to be more readily integrated with the aircraft structure and the aerodynamics of the wing. It is expected that distribution of propulsive flow over the wing surface will allow circulation control on the wing through both suction and tangential blowing. Circulation control on the wing provided by the embedded distributed propulsion systems would provide unprecedented maximum lift coefficients, with associated reduction in take-off and landing distance. Military transition targets would be short take-off and landing airlift and transport vehicles, benefiting from improvements

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possible in take-off and landing distance. The program will conduct a series of design, sizing and demonstration efforts, culminating in either a wind tunnel or flight test of a circulation control wing using distributed propulsion.

(U) Program Plans:
FY 2008 Plans:
- Conduct trade studies on aircraft sizing for short field take-off and landing.
- Evaluate conceptual designs of distributed embedded propulsion concepts and assess aerodynamic performance.

FY 2009 Plans:
- Determine engine requirements for distributed propulsion system.
- Initiate design of distributed embedded propulsion experiments.

	FY 2007	FY 2008	FY 2009
Laminar Flow Flight Demonstration	0.200	3.800	4.800

(U) The Laminar Flow Flight Demonstration effort will explore the development of an extended laminar flow wing, with the potential for a drag reduction of up to 25% compared to a typical fully turbulent wing. Crossflow instabilities dominate the transition process for swept wings. Recent advances in theoretical understanding of the crossflow receptivity and transition process have led to innovative, passive control concepts for the crossflow transition process. Test facilities are not available to demonstrate this flight concept in a quiet flow environment at flight-representative Reynolds numbers and Mach numbers. Flight testing a swept wing laminar flow control concept appears to be the most direct route to validation of this technology, enabling future aircraft designs to adopt passive crossflow control devices as a proven technology.

(U) Program Plans:
FY 2007 Accomplishments:
- Conducted initial assessment of range of applicability of crossflow control approaches and candidate platforms.

FY 2008 Plans:
- Conduct trade study of impact and design constraints for laminar flow wings.

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FY 2009 Plans:
- Conduct feasibility study of high Reynolds number flight test.
- Initiate design of flight test experiment.
- Initiate design of laminar flow wing for demonstration.

	FY 2007	FY 2008	FY 2009
Unmanned Persistent Parafoil System (UPPS)*	1.000	3.250	1.000

*Formerly Long Endurance Autonomous Powered Powerfoil (LEAPP).

(U) The goal of the Unmanned Persistent Parafoil System (UPPS) program is to develop and integrate the enabling technologies and system capabilities required to demonstrate a vehicle with large payload and long endurance characteristics capable of taking off and landing on the back of a small ship. The enabling technologies are precision guidance, autonomous operations, parafoil aerodynamic performance, and parafoil integration with sensors/antennas. The UPPS will provide 48-hours of continuous organic air-support to small ground units or small marine vessels with a 200lb surveillance and communication package. In addition, the UPPS will have flexibility to be deployed rapidly and will be affordable based on modular system design and construction.

(U) Program Plans:

FY 2007 Accomplishments:
- Developed initial prototype and demonstrated feasibility flight performance.

FY 2008 Plans:
- Conduct system level tests for specific missions and concept of operations.

FY 2009 Plans:
- Initiate final program demonstration and prepare for transition.

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	FY 2007	FY 2008	FY 2009
Disc-Rotor Compound Helicopter	0.000	3.000	3.200

(U) The goal of the Disc-Rotor Compound Helicopter program is to design and demonstrate the enabling technologies required to develop a new type of compound helicopter capable of high-efficiency hover, high-speed flight, and seamless transition between these flight states. The aircraft will be equipped with a rotating circular wing having blades that can be extended from the disc edge, enabling the aircraft to take-off and land like a helicopter. Transition from helicopter flight to airplane flight would be achieved by gradually retracting and stowing the blades as the circular wing assumes the task of lifting. An aircraft capable of long range high speed (300-400 kts) and Vertical Take-off and Landing (VTOL)/hover will provide mobility and responsiveness for troop and cargo insertion, satisfy an ongoing military interest for higher speed VTOL and hover capable vehicles, be survivable and bridge the gap in helicopter escort and insertion missions. The enabling technologies are disc-rotor configuration, circulation control, seamless reversible transition between hover and wing borne flight, and loading/center-of-pressure control. Specific objectives of the Disc-Rotor Compound Helicopter program include: characterization of the flowfield environment created by a disc-rotor, demonstration of disc-rotor configuration, and design and demonstration of prototype vehicle transition dynamics and operational utility.

(U) Program Plans:

FY 2008 Plans:

- Develop a conceptual design and technical approach.
- Identify, develop, and demonstrate the critical enabling technologies required to meet the performance goals.

FY 2009 Plans:

- Design an integrated scaled concept demonstrator vehicle that proves the viability of the disc-rotor concept.

	FY 2007	FY 2008	FY 2009
Integrated Compact Engine Flow Path	0.000	3.500	4.600

(U) The goal of the Integrated Compact Engine Flow Path program is to develop a structurally integrated, load bearing, composite, thrust vectoring nozzle. Integration of compact inlets and nozzles that are lightweight and survivable continue to be a challenge in military aircraft

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design. Existing metal nozzles are cantilevered off the engine face and the airframe, with an overlap region to allow for thermal growth. This approach to nozzle integration results in heavy, high maintenance nozzles and is structurally inefficient. It also poses a significant engine integration challenge and can drive vehicle sizing. A fully integrated nozzle, designed to take airframe loads through the nozzle, and built of a high temperature ceramic, would address the weight and structural integration problems directly. This approach would also be compatible with fluidic thrust vectoring and would result in a more compact, lighter, and more durable nozzle. Indications are that installed weight reductions of over 50% compared to existing state of the art thrust vectoring nozzles are feasible. This program will design, develop, and demonstrate a full scale, fluidic thrust vectoring nozzle in a direct connect engine test.

(U) Program Plans:

FY 2008 Plans:

- Perform design trade studies to develop a preferred nozzle design as well as a development and demonstration plan.
- Perform materials and small-component testing on a structural element in combined thermal/pressure environments representative of nozzle operating conditions.

FY 2009 Plans:

- Perform design studies for a dynamic loads test nozzle.
- Perform detailed design of a ceramic matrix composite nozzle to be built of high temperature ceramics.

	FY 2007	FY 2008	FY 2009
Active Rotor	0.000	3.380	5.237

(U) The goal of the Active Rotor program is to develop and demonstrate enabling technologies that greatly enhance rotor control and performance, availability, sustainability, and affordability. Performance enhancement objectives are 25-50% improvement in endurance, range, and payload of existing helicopters. Enabling technologies include a dynamically controlled rotor, light-weight high-bandwidth on-blade actuators, and integrated vehicle flight control technologies. Over the past several decades, improvements in helicopter rotor performance have not kept pace with the increasing demands of the warfighter. This is apparent today in the high altitude environment of Afghanistan, where troop and materiel transport missions that are normally performed by the UH-60 Black Hawk are being performed by the much larger CH-47 Chinook due to the loss of performance in high/hot conditions. The Active Rotor program will mature the technologies to enable military aircraft such as

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the Black Hawk to operate effectively in this environment. The Active Rotor program will focus on development and demonstration of advanced technologies for application to future platforms, with demonstration on a fielded system to facilitate upgrade of current multi-service rotorcraft rotor systems and will demonstrate technologies with broad applicability to military and commercial helicopters.

(U) Program Plans:
FY 2008 Plans:
– Identify and develop advanced lightweight high-bandwidth on-blade actuators, and assess dynamically controlled rotor performance.
FY 2009 Plans:
– Conduct component technology demonstrations and initiate preliminary design of the Active Rotor System.
– Perform sub-scale wind tunnel test of the Active Rotor System.

	FY 2007	FY 2008	FY 2009
Lightweight High Efficiency Aircraft Power Generation	0.000	3.250	5.000

(U) The goal of the Lightweight High Efficiency Aircraft Power Generation program is to develop a lightweight, fuel-efficient system to deliver up to 2 megawatts (MWs) of electrical power to support the integration of high energy laser weapons on airborne platforms. Conventional power generating systems of this scale are large and heavy, respond too slowly to power demands from the laser system, are not fuel efficient, and impose a significant performance penalty on the host aircraft. The program will develop and demonstrate a novel power generation approach that is capable of providing full power (1-2 MW at 25,000 ft/0.8 Mach) within 0.1-2.0 seconds and that can operate in a fuel-efficient standby mode. The power generation system will be tailored for potential integration on existing bomber and transport aircraft with minimal integration penalties and will support both high energy laser and high power microwave weapons.

(U) Program Plans:
FY 2008 Plans:
– Conduct system trade studies and preliminary design.
FY 2009 Plans:
– Demonstrate power generation components to evaluate output range, responsiveness, and efficiency.

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– Initiate fabrication of demonstrator.

	FY 2007	FY 2008	FY 2009
Nightingale	0.000	0.000	2.000

(U) The Nightingale program will design, develop, integrate and demonstrate the enabling technologies and system capabilities required to perform fully autonomous, just-in-time medical response and evacuation using an autonomous, airborne, man-rated platform. The Nightingale system integrates advanced life support capabilities into a small unmanned (or optionally piloted) air vehicle that can serve as a low cost, high availability air ambulance deployed forward alongside troops in contact. Such a capability offers the opportunity to revolutionize combat casualty care provided by embedded medics and medical teams under adverse and hostile conditions. Nightingale will be capable of unmanned high speed evacuation of casualties to higher echelon, secondary care facilities and may be prepositioned close to combat areas to minimize evacuation timelines. The man-rated Nightingale system will also be capable of autonomous combat search and rescue (CSAR) to eliminate the threat to CSAR crews.

(U) Technical challenges include intelligent, autonomous flight behavior, sensor integrated guidance and control to enable flight in complex terrain, fully autonomous selection and use of suitable landing locations, dual mode (ground and flight) propulsion, collaboration/coordination with human combat medics, and safe and rapid autonomous launch and return to advanced field medical facilities.

(U) Program Plans:
FY 2009 Plans:
– Conduct system trades, effectiveness, and affordability through modeling and simulation.
– Develop sufficient system concept fidelity to validate program goals and objectives.
– Develop Nightingale preliminary design, risk management plan, and technology and system maturation plan.

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	FY 2007	FY 2008	FY 2009
Adaptive Morphing Super-Maneuver Aircraft (AMSMA)	0.000	0.000	3.000

(U) The goal of the Adaptive Morphing Super-Maneuver Aircraft (AMSMA) program, a maturation of the Morphing Aircraft Structure (MAS) program previously funded in PE 0602715E, Project MBT-01, is to demonstrate a technology leap forward to a generation after next aircraft vehicle concept that can provide revolutionary military utility in a number of air vehicle applications and missions. It will build on the demonstrations of the MAS program which established that air vehicles able to seamlessly change configuration in flight are capable of achieving near optimum performance across a range of contradictory missions that would not otherwise be possible with conventional designs. This program will demonstrate an advanced morphing, highly maneuverable air vehicle. Employing a combination of enabling technologies, including asymmetric wing sweep, fore and aft wing translation, and aero-elastic wings with adaptive hinge-less control actuation, AMSMA aims to dispense with traditional flying controls and seeks to achieve efficient aerodynamic and maneuver performance over a wide range of speeds and altitudes. The ability to super-maneuver, employing bird-like flight excursions, offers the warfighter new combat approaches to target prosecution. The concept will introduce a capability whereby one aircraft with the ability to effect multiple radical configuration changes is enabled to conduct a range of missions optimally; this provides the prospect of significant affordability gains through reducing the number of different aircraft types in existing military fleets. The AMSMA program will develop a morphing demonstrator vehicle to expand the flight envelope and to demonstrate revolutionary control and a super-maneuver capability through a series of measurable flight experiments. The anticipated transition partner is the Air Force.

(U) Program Plans:

FY 2009 Plans:

- Identify, develop and demonstrate the critical enabling technologies required to meet the performance goals.
- Design an integrated morphing concept demonstrator vehicle that changes configuration to achieve optimized mission segment performance (e.g. high-speed dash), to achieve maneuver capability including extreme new maneuvers and to optimize tailored survivability.

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	FY 2007	FY 2008	FY 2009
Micro Adaptive Flow Control (MAFC)	4.419	0.000	0.000

(U) Micro Adaptive Flow Control (MAFC) technologies have enabled control of large-scale aerodynamic flows using small-scale actuators. MAFC technologies combined 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 were explored for applications such as download and drag reduction for air vehicles, facilitation of long-range flight with reduced fuel consumption and logistical implications using vortex mitigation, adaptive lift-on-demand for agile missiles and uninhabited tactical aircraft, supersonic boundary layer control, lightweight gas turbine engines, and low-drag, non-intrusive methods to aerodynamically steer projectiles for extended range and precision.

(U) Program Plans:

FY 2007 Accomplishments:

- Completed sled design and fabrication for High Frequency Excitation for Supersonic Weapons Release (HIFEX) test.
- Completed Mach 2.0 HIFEX system sled test.
- Completed HIFEX system design and fabrication and executed full-scale technology demonstrations.

	FY 2007	FY 2008	FY 2009
Miniature Propulsion Concepts	5.334	0.000	0.000

(U) This program developed concepts for small scale class propulsion systems suitable for Small Unmanned Air Vehicles (UAVs). Small gas turbine engines are typically very inefficient, below 7%, for engines below 10 horsepower. This program developed gas turbine engines under 10 horsepower with a power density greater than 2HP/pound and a thermal efficiency greater than 25%. In addition, novel concepts for developing micro UAV's that emulate and/or borrow propulsion approaches from birds were developed. These provided a unique Intelligence, Surveillance, and Reconnaissance (ISR) capability for the dismounted soldier.

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(U) Program Plans:
FY 2007 Accomplishments:
- Demonstrated multiple payloads.
- Deployed approximately 100 vehicles with the USMC for in theater testing; logged over 1,600 missions and 1,000 flight hours.
- Transitioned WASP Micro UAV Block III variant to Air Force; it is now a program of record.
- Completed design of subsystems including compliant-foil bearings, alternator and recouperator.

	FY 2007	FY 2008	FY 2009
Peregrine Counter UAV	3.924	0.000	0.000

(U) The Peregrine Counter Unmanned Air Vehicle (UAV) program evaluated low-cost concepts to counter small UAV threats. Peregrine investigated development of a UAV interceptor system capable of providing point cued area defense against small UAV threats using a range of technologies to identify, track, and destroy or otherwise counter multiple threats. Candidate sensor and weapon technologies included acoustic, optical, radio frequency, kinetic, directed energy, and physical envelopment. System technologies included high-assurance integrated command, low-cost persistent unmanned operations, and precise air trajectory control.

(U) Program Plans:
FY 2007 Accomplishments:
- Examined candidate technologies.
- Developed concept design.

	FY 2007	FY 2008	FY 2009
High Speed / Hypersonic Reusable Demonstration	20.700	0.000	0.000

(U) This program was a joint DARPA/Air Force initiative to design, develop, and demonstrate combined cycle engine components for a reusable hypersonic cruiser in conjunction with the Falcon program (PE 0603287E, Project SPC-01). Ultimately, the studies and developments

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under this program may result in the first controllable, recoverable, and reusable hypersonic system demonstration. Initial designs allowed for either a manned or unmanned version, and provided viable options for long-range strike and affordable access to space. The program was divided into two efforts—the High Speed Turbine Engine Demonstration (HiSTED) and the Scramjet Engine Demonstration (SED).

- The HiSTED objectives were to design, fabricate, and ground test a high Mach expendable turbine engine capable of Mach 3-4+ operation. The objective of the ground demonstration was to verify, via simulated altitude testing, that engine performance and operability characteristics at key transonic and maximum Mach/altitude cruise flight conditions meet anticipated system application needs.

- The SED effort sought to design, fabricate, and fly a hypersonic vehicle powered by the HyTech scramjet engine over a broad range of Mach numbers. The SED flight vehicle was boosted to Mach 4.5 using a modified ATACMS booster motor. Following separation from the booster, the air vehicle, now designated X-51, accelerated under scramjet propulsion to Mach 6.

(U) Program Plans:

– High Speed Turbine Engine Demonstration (HiSTED)
FY 2007 Accomplishments:
-- Conducted Critical Design Reviews of two engine concepts.
-- Completed high temperature turbine components design and fabrication of one engine concept.
-- Assessed supercritical fuels.
-- Assessed high temperature lubrications and bearings.
-- Performed component integration for one engine concept.

– Scramjet Engine Demonstration (SED)
FY 2007 Accomplishments:
-- Conducted a critical design review for the air vehicle.
-- Conducted freejet testing of the X-1 fuel-cooled scramjet engine.
-- Initiated fabrication of the air vehicles to be used in flight testing.

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	FY 2007	FY 2008	FY 2009
Flare Aero Structures	0.631	0.000	0.000

(U) The Flare Aero Structures program explored and developed a new concept for the take-off and landing of a fixed wing aircraft. The landing field requirement for a fixed wing aircraft limits use in both confined (e.g. urban) and remote unprepared areas. This program sought to explore unsteady aerodynamics during rapid pitch up or flare landing maneuvers. It is known that very high lift coefficients can be obtained for a short period of time during such a maneuver. The technical challenge was to develop the aero structures, control effectors and control logic that would allow for a practical application of this phenomenon to a fixed wing aircraft to enable landing in a very short distance.

(U) Program Plans:
FY 2007 Accomplishments:
– Developed aerodynamic models for dynamic lift increments.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Network Centric Enabling Technology TT-13	52.920	72.699	77.588	83.002	75.045	76.531	76.530

(U) Mission Description:

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

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

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(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Networked Embedded Systems Technology (NEST)	4.000	4.000	3.000

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

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

(U) Program Plans:

FY 2007 Accomplishments:

- Developed tools for the automatic composition and verification of application-specific coordination service packages; demonstrated the utility of these tools in a fully integrated system consisting of a large network of heterogeneous sensors.
- Developed tools for remotely reprogramming large scale sensor networks and services for authentication and data encryption in those networks.
- Developed and populated a repository of customizable/adaptable services for real-time coordination and synthesis that support military applications.

FY 2008 Plans:

- Develop prototype pulsing and sensing system to measure phenomenology, insertion losses, and radiation efficiency.

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FY 2009 Plans:
- Demonstrate, in non-real time experiments, target localization and tracking in a realistic multi-story urban structure.
- Conduct final field experiments and Military Utility Assessments.

	FY 2007	FY 2008	FY 2009
Combat Zones That See (CZTS)	5.000	7.000	6.000

(U) The Combat Zones That See (CZTS) program improves the situational awareness, effectiveness, and safety of U.S. military forces in foreign urban environments (e.g., Mozul). CZTS provides close-in sensing and extended reconnaissance capabilities using a network of video sensors. The system tracks vehicles over urban areas using sparse arrays of video cameras, automatically detecting vehicles that may be involved in hostile activities based on the observed tracks. This network produces an extreme amount of raw data, precluding human analysis, so advanced video understanding algorithms embedded in commercial-off-the-shelf hardware systems monitor the video feeds automatically. As processing requirements become well understood, novel image-processing chips will be integrated and interleaved with focal plane arrays within a conventional camera architecture, and a fully-compatible communications link developed to support a video-based system for perimeter defense. CZTS will enable vehicle identification with a 10,000-fold reduction in the bandwidth required to transmit key data across the camera network and will provide the capability to track vehicles non-continuously across extended distances. The CZTS goal is to demonstrate technology packaged into a flexible ground-deployed system.

(U) Program Plans:

FY 2007 Accomplishments:
- Developed, installed overseas, and evaluated a force protection prototype that employs approximately thirty cameras.
- Demonstrated sustained tracking of individual vehicles using sensors whose fields-of-view do not overlap.
- Used vehicle track data to calibrate cameras, learn patterns of activity, and retrieve similar or related events from a track database.

FY 2008 Plans:
- Employ motion-pattern analysis to assist in finding common elements among collected tracks.
- Develop methodologies for the efficient and timely management of the video network.

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- Simulate the processing of pixel information in the image plane of video camera, to distinguish fundamental features of humans/animals/machines, such as the cooperative movement of aggregate pixel features.

FY 2009 Plans:

- Demonstrate semiconductor circuitry for integration within the image plane of the camera, to process pixel information in an energy-efficient way for identification for perimeter intrusion.
- Demonstrate the completed video sensor system, for actual determination of human/animal/machine penetration of a perimeter defensive system.
- Develop, install, and evaluate a rapid deployment prototype using approximately 100 rapidly deployed cameras.

	FY 2007	FY 2008	FY 2009
Automated Battle Management	13.400	20.418	20.328

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

(U) The Collaborative Networked Autonomous Vehicles (CNAV) program will be the primary demonstration of Automated Battle Management Techniques. It will develop autonomous control methods to cause a distributed set of unmanned undersea vehicles to self-organize and distribute tasks through judicious transactions conveyed over a shared communications network. CNAV will utilize these capabilities to provide submerged target detection, localization, and tracking in restrictive littoral waters. CNAV provides this capability by creating a field of dozens or hundreds of vehicles, networked through acoustic wireless communications. The vehicles work collaboratively and autonomously to detect, classify, localize and track target submarines transiting the field. The field self-organizes to adapt to changes in target locations, environmental conditions, and operational factors. A reach-back capability allows reporting of field health and enables high-level orders and

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

(U) Program Plans:

FY 2007 Accomplishments:

- Developed secure, robust underwater wireless communications and networking.
- Conducted live demonstration with thirty-eight underwater vehicles collaborating.

FY 2008 Plans:

- Perform intelligent routing of threat characteristic and track data through the field to alert CNAV nodes down stream to position or reposition for target pursuit and intercept.
- Demonstrate fully autonomous and collaborative CNAV field deployment, autonomous field set-up and self-localization, distributed common tactical operational picture, self-healing and reconfiguration, and threat pursuit and interception.

FY 2009 Plans:

- Demonstrate collaborative automated target detection, classification, localization and tracking.

	FY 2007	FY 2008	FY 2009
Home Field	12.369	15.000	13.000

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

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(U) Drawing upon technologies developed in the Home Field program, the Urban Photonic Sandtable Display (UPSD) program develops revolutionary interactive holographic displays for complex volumetric 3-D data to replace current 3-D visualization technologies that are either static or have limited effective field-of-view. Current technologies include traditional holography, computer graphics on 2-Dimensional (2-D) screens, slice stacking, parallax autostero, and goggles/glasses. These techniques not only give a poor image quality and poor movement, they also are not created quickly and do not allow for collaborative viewer interaction. The desire to improve these components has launched the development of the UPSD. A monochrome active hogel-based proof-of-concept display and further developed module have been validated by transforming computer data to optical data, making sophisticated integration possible to optimize image quality. The UPSD program will develop an affordable 3-D display that operates at full video rate, displays RGB color, increases viewing angle, and increases display size. The result will be the world's first full-motion, full aspect 3-D imaging technology system.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated a 3-D model method that used distributed video and LADAR cameras in a mixed urban environment.
- Conducted a validation demonstration on a 1-foot by 1-foot active hogel design for the UPSD.
- Validated a monochrome active hogel-based proof-of-concept display by transforming computer data into optical data, making sophisticated integration possible to optimize image quality.
- Fully developed an active hogel module to provide necessary optical and electrical performance.

FY 2008 Plans:

- Demonstrate the ability to extract architectural features, such as windows and doors, from close-in imagery.
- Build and customize the active hogel modules into tiles and align tiles in superstructure for 2-foot by 2-foot and 3-foot by 3-foot systems.

FY 2009 Plans:

- Research advanced technologies for improving the production methods of pixilated emissive displays.
- Demonstrate the final system at full video rate, color display, and with the possibility of tiling to larger display scales (e.g., 6-feet by 6-feet).

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	FY 2007	FY 2008	FY 2009
Adaptive Reflective Middleware Systems (ARMS)	5.860	8.000	4.000

(U) The Adaptive and Reflective Middleware Systems (ARMS) program is developing an integrated open system computing and information architecture. The initial focus is on the Total Ship Computing Environment in the DD-1000 Future Surface Combatant Family of Ships; however, the technology is applicable to other network-centric DoD systems. Autonomous computing systems require middleware and frameworks that adapt robustly to changes in environmental conditions. The ARMS environment dynamically executes all tasks and mission applications optimized at the platform level, rather than the subsystem level, coordinating the exchange of information predictably, scalably, dependably, and securely among shipboard entities. The ARMS program is developing automated certification technology that will deliver assured deployment of these dynamically managed military computing systems.

(U) Program Plans:

FY 2007 Accomplishments:

- Defined prototype reflective techniques for synthesizing optimized distributed, real-time, and embedded middleware.
- Developed required information models, algorithms, and technologies; developed technologies to configure customizable, standards-compliant middleware and applications.
- Developed robust adaptive protocols, algorithms, patterns, and technologies that exploit standards-compliant middleware.
- Developed and captured design expertise in information models.
- Formalized the successful techniques and constraints associated with building, generating, and validating middleware frameworks and protocol/service components for the DDG-1000 baselines.
- Demonstrated mature, standards-based middleware technologies for transition to the DDG-1000 Surface Combatant Family of Ships.

FY 2008 Plans:

- Develop simulation and analysis component that generates thousands of plausibly certifiable system configurations, performs failure and timing analysis functions, and uses metrics such as co-failure probability to evaluate and rank configurations.
- Develop an automated testing component that creates and deploys tests across a distributed testbed of computers, produces a subset of certifiable configurations, and learns associations between configurations to operational conditions.
- Develop interface for certification authorities to review performance metrics across certified configurations.

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– Evaluate ability to automatically identify certifiable configurations in a representative subset of possible states within a dynamically managed computing environment.

FY 2009 Plans:

– Develop shipboard operational selector component that chooses and deploys the best certified configuration at runtime.
– Evaluate ability to automatically identify certifiable configurations in full DDG-size scenarios using emulated applications.
– Define requirements for integration of automated certification technology with existing standards and processes.

	FY 2007	FY 2008	FY 2009
Integrated Crisis Early Warning System (ICEWS)	5.747	11.000	13.608

(U) The Integrated Crisis Early Warning System (ICEWS) program develops and integrates a set of data analysis tools into a unified information system to support Theater Security Cooperation. The ICEWS system monitors, assesses and forecasts leading indicators of events that make countries vulnerable to crises. ICEWS technologies include quantitative and computational social science modeling and simulation, scenario generation, ontological modeling of security problems, advanced interactive visualization techniques, and agent-based programming. When integrated, these tools allow combatant commanders and their staff to understand and anticipate conditions that precipitate instability and conflict - while there is still time to influence them. ICEWS also helps anticipate unintended consequences of actions taken to influence or remediate situations - consequences that may be delayed by months or years.

(U) Program Plans:

FY 2007 Accomplishments:

– Obtained and organized a large corpus of data describing a representative set of countries and regions in the Pacific Command (PACOM) that are expected to range from stable to highly unstable social dynamics.

FY 2008 Plans:

– Augment existing social science models with emerging computational social science models and theories.
– Build tools to automatically translate the data corpus into a form usable by quantitative and computational social science models.
– Develop new crisis monitoring and forecasting models across multiple timescales and levels of analysis.
– Integrate in a real-time analytical system.

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FY 2009 Plans:
- Link Theater Security Cooperation (TSC) resources to factors driving country and regional instability to assess mitigation options.
- Conduct regular experiments to assess predictions in an operational environment.
- Develop tools that can be transitioned to the staff at Combatant Commands (PACOM HQ).
- Create a rigorous analytic capability to predict how alternative courses of actions (COAs) are likely to alter adverse emergent patterns of behavior in order to determine ways more beneficial to U.S. interests.
- Create realistic human leadership models for use in policy analysis, military combat models, and other venues.

	FY 2007	FY 2008	FY 2009
Very High Speed Torpedo Defense	0.000	4.156	5.638

(U) The Very High Speed Torpedo Defense program will develop concepts for U.S. ship defense systems to defeat very high-speed (250 knot) rocket-powered super-cavitating torpedoes currently under development by other nations. Queued by a ship's sonar system, the torpedo can be identified and localized using a large search volume laser-radar tracking system that can be used to compute a firing solution. The torpedo will then be engaged using specially designed high-speed projectiles (also super-cavitating) fired from the ship to neutralize the incoming threat.

(U) Program Plans:

FY 2008 Plans:
- Validate preliminary sensor and weapon concepts.

FY 2009 Plans:
- Design and test final system components, including the laser sensor, the cueing and targeting mechanism, and the projectile weapons.
- Demonstrate and test the entire system using test rigs and lake facilities.
- Conduct a final series of ocean tests in a variety of sea state conditions.

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	FY 2007	FY 2008	FY 2009
Visualizing the Info Ops Common Operating Picture (VIOCOP)	0.000	3.125	0.000

(U) The goal of the Visualizing the Info Ops Common Operating Picture (VIOCOP) program is to research methods to provide a commander with a standardized and logical way of depicting the impact of Information Operations on conventional missions. Great strides have been made in digitizing the battlefield and developing standardized sets of representations for the commander to visualize the physical battlefield. However, the area of information operations concerns operations that do not map cleanly to "kinetic" operations and geography. An informationally rich and succinct visual representation of non-geographic, non-kinetic information operations is needed to appropriately assess progress during an information operations campaign as well as to understand interactions with ongoing conventional operations. Information operations require the commander to understand issues and impacts that may be well outside his defined area of responsibility but have significant consequences to the success (or failure) of a mission.

(U) Program Plans:
FY 2008 Plans:
- Research a meaningful symbology and depiction of information operations concepts for the broadest definition of information operations (to include technical, social, geographic, cultural, tactical, cyberdefense, etc.).
- Research human-computer interfaces to visualize and manipulate information operations data.
- Research mechanisms to integrate the tactical picture with the information operations information.

	FY 2007	FY 2008	FY 2009
Laser Guided Bullet	0.000	0.000	5.014

(U) The Laser Guided Bullet program develops and demonstrates a maneuvering bullet that follows a laser beam to an intended target. Technology development includes the design and integration of aero-actuation controls, power sources, and laser sensors into a limited volume ($2cm^3$) projectile to withstand a high acceleration environment. When integrated and tested, this system will make every shooter with any

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50-caliber weapon a precision sniper at greater than 2 KM range. The Laser Guided Bullet technology is planned for transition to the Army by FY 2010. This program transfers from PE 0603764E, project LNW-01 in FY 2009.

(U) Program Plans:
FY 2009 Plans:
- Design sensor guidance system.
- Perform system integration and validation.
- Conduct in-weapon testing.

	FY 2007	FY 2008	FY 2009
Digital Media Exploitation (MEDEX)	0.000	0.000	4.000

(U) The Digital Media Exploitation (MEDEX) program will develop technology to extract intelligence of tactical value from digital media found on computers captured in the field of operations. MEDEX will automatically search content found on computers captured in the field and identify data of high intelligence value. MEDEX will develop multiple exploitation algorithms that can quickly index, search, and analyze all digital file types: text documents, audio files, images, videos, applications, etc. Additionally, MEDEX will develop network analysis algorithms that identify significant connections between information found on multiple computers. The goal of the MEDEX program is to reduce the exploitation time for digital media from months to minutes.

(U) Program Plans:
FY 2009 Plans:
- Develop automated media exploitation algorithms for multiple operating systems and file types.
- Develop integrated exploitation system that produces ranked lists of summarized content found on digital media.
- Demonstrate intelligence extraction by testing digital media with simulated data.

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	FY 2007	FY 2008	FY 2009
Strategic Communication Assessment and Analysis System (SCAAS)	0.000	0.000	3.000

(U) Strategic communications are focused, integrated efforts to understand and engage key audiences in order to create, strengthen, or preserve conditions favorable for the advancement of U.S. government interests, policies, and objectives. This is accomplished through the use of coordinated programs, plans, themes, messages, and products synchronized with the actions of all elements of national power. Effective strategic communication is central to our ability to effectively deter adversaries, reassure allies, dissuade future competitors, and communicate our resolve to defeat enemies should deterrence fail. The Strategic Communication Assessment and Analysis System (SCAAS) program will develop new theories, concepts, tools and systems to formulate and assess sound strategic communication strategies and measure their effectiveness in influencing allies, adversaries, and other constituencies around the world. This capability would have dramatic value to Combatant Commands (COCOMS) as it would enable the influencing of diverse people and organizations abroad towards U.S. National Security interests.

(U) Program Plans:
FY 2009 Plans:
- Develop models to continuously analyze/assess the strategic communications "information environment" from multiple perspectives and levels of analysis, including audience, context transmitters, and time.
- Develop models for mapping influences to perceptions (such as influences of cultural context, cognitive and emotional biases on message reception and interpretation).

	FY 2007	FY 2008	FY 2009
Urban Warfare Robotic Surveillance (URS)	4.000	0.000	0.000

(U) The Urban Warfare Robotic Surveillance System (URS) program developed new mobile sensor systems, carried on both long-endurance ground and short-endurance air platforms, to support warfighter operations in constrained urban environments. URS explored a mix of sensor technologies (normal and infrared video, active optics, radar, acoustic, magnetic, chemical, and RF direction finding). Sensors were tested in environments characterized by complex multi-path propagation, limited lines-of-sight, and frequent obscuration. Platforms and sensor networks

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were designed to operate in urban exterior, underground, and indoor environments. Communications repeaters and routers provided terrestrial connectivity to all platforms and provided autonomous operation if communications are interrupted. A program demonstration also delivered a prototype robotic squad for testing. The URS program also supported the DARPA Urban Challenge.

(U) Program Plans:
FY 2007 Accomplishments:
- Exercised test platforms in a series of increasingly difficult mission/environment combinations.
- Improved sensors or algorithms that limit performance.
- Funded technology development contracts and program planning support for the DARPA Urban Challenge.

	FY 2007	FY 2008	FY 2009
Diagnostic Network Economies	1.104	0.000	0.000

(U) The Diagnostic Network Economies program improved the speed, accuracy, and efficiency of fault diagnosis in distributed systems that provide support for crucial network centric military operations, such as transmitting a common operational picture and maintaining information dominance. As network centric warfare systems are introduced, the management systems that are needed to operate these networks must become exceptionally robust. The Diagnostic Network Economies program substantially reduced the risk

(U) associated with network-centric operations, and at the same time assures the agility of U.S. forces by developing effective network fault diagnosis capabilities that minimize the logistical footprint associated with that aspect of network management and reduce the opportunities for human error in the process.

(U) Program Plans:
FY 2007 Accomplishments:
- Identified the minimum necessary cryptographic machinery to perform adversary detection using secure packet sampling.
- Derived bounds on accuracy of stealthy adversary detection and localization.
- Prototyped a “stealth probing” system.

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	FY 2007	FY 2008	FY 2009
R31 Systems: Next Generation of Intelligent Communications	1.440	0.000	0.000

(U) Selected and continued to fund initiatives for the next generation of intelligent communications.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	270.513	301.741	285.264	257.799	256.392	273.508	263.600
Materials Processing Technology MBT-01	144.762	191.151	154.158	151.433	161.954	179.070	169.163
Biologically Based Materials and Devices MBT-02	125.751	110.590	131.106	106.366	94.438	94.438	94.437

(U) Mission Description:

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

(U) The major goal of the Materials Processing Technology project is to develop novel materials, materials processing techniques, mathematical models, and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling for improvements in logistics.

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

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

	FY 2007	FY 2008	FY 2009
Previous President's Budget	298.147	306.022	303.363
Current Budget	270.513	301.741	285.264
Total Adjustments	-27.634	-4.281	-18.099
Congressional program reductions	-20.000	-14.081	
Congressional increases	0.000	9.800	
Reprogrammings	0.000		
SBIR/STTR transfer	-7.634		

(U) Change Summary Explanation:

FY 2007	The decrease reflects the SBIR/STTR transfer and Section 8043 Rescission.
FY 2008	The decrease reflects a PE execution adjustment and reductions for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions; offset by congressional adds for Economic Production of Coal to Liquid Fuel, Reduce Environmental Impact of Coal to Liquid Fuels, and Strategic Materials and Silicon Carbide Optics.
FY 2009	The decrease reflects the transition of the Prognosis Program to the U.S. Air Force and rephasing of several materials programs.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Materials Processing Technology MBT-01	144.762	191.151	154.158	151.433	161.954	179.070	169.163

(U) Mission Description:

(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 improvements in logistics.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Materials Processing and Manufacturing	11.710	14.999	14.000

(U) The Materials Processing and Manufacturing thrust is exploring new manufacturing and processing approaches that will dramatically lower the cost and decrease the time it takes for DoD systems to be fabricated. It will also develop approaches that yield new materials and materials capabilities that cannot be made through conventional processing approaches. Included are disruptive manufacturing approaches for raw materials and components.

(U) Program Plans:

FY 2007 Accomplishments:

- Established digital representation of microstructure across the nano-, micro- and meso-scales to effectively and quantitatively describe structures and features of interest.
- Developed data synthesis and management techniques for efficient information storage, manipulation and utilization by physics-based models.

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- Established protocol for reconstruction of digital microstructure at all appropriate length scales.
- Demonstrated carbon nanotube filaments from electrospun precursor polymer fibers.
- Demonstrated composite fibers incorporating carbon nanotubes in graphite derived via commercially scalable fiber production methodologies.
- Designed and built a maskless optical imaging system (MOIS) suitable for large area lithographic patterning of formulations used to make cores and shells for casting of internally cooled superalloy blades.
- Completed screening activities to determine the best candidate resin, fiber, and film adhesive to be used for out of the autoclave manufacturing of polymer matrix composites for aerospace applications.

FY 2008 Plans:

- Demonstrate capability to capture salient features of microstructure, convert data into functional entries for physics-based model parameters, and demonstrate active reconstruction of microstructure for visualization.
- Demonstrate integration with digital microstructural representation in order to illustrate dynamic effects on salient features in response to extrinsic stimuli.
- Demonstrate carbon fiber properties that are in excess of 1000 ksi in strength, 50 msi in modulus and 2% strain to failure.
- Design, build, and operate large area lithographic exposure machine subsystems to produce ceramic cores for casting of superalloy turbine blades.

FY 2009 Plans:

- Demonstrate integration with digital microstructural representation in order to identify critical features for design of material composition and processing to achieve microstructure for a set of desired properties.
- Demonstrate integration of physics-based predictive models of materials performance with digital microstructural representation.
- Demonstrate carbon fiber properties that are in excess of 1800 ksi in strength, 60 msi in modulus and 3% strain to failure.
- Demonstrate economical tooling for low volume production of polymer matrix composite (PMC) (10-25 units of a CH-47 helicopter ramp) that operates at less than 200 degrees Celsius cure temperature. Verify PMC subcomponent (containing critical details) meets static, fatigue, and destructive evaluations.

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	FY 2007	FY 2008	FY 2009
Structural Materials and Coatings*	11.550	11.800	8.137

*Previously this was part of Materials Processing and Manufacturing.

(U) The Structural Materials and Coatings thrust is exploring and developing new materials that will provide enhanced structural and/or surface properties for DoD applications. Included are approaches that avoid corrosion, provide superior strength at greatly reduced material density, provide the basis for a new generation of structural composite materials, and enable prolonged lifetimes for DoD systems and components.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated viability of the electrochemical reduction of TiO2 to titanium at a current efficiency greater than 80%.
- Entered into an agreement with industrial partner to scale-up the technology.
- Demonstrated coatings with outstanding corrosion resistance suitable for both Naval applications and long term radioactive storage capability.
- Demonstrated second generation amorphous metals with high damage tolerance while maintaining very high strength and hardness.
- Demonstrated that ultralight aluminum, calcium, magnesium alloys for space applications can be fabricated using conventional injection molding technologies.
- Demonstrated Al based alloys for turbine fan blade applications that promise increased performance and reduced fuel consumption.
- Demonstrated corrosion resistant material coatings and non-skid capability for naval combatant ships.

FY 2008 Plans:

- Develop process for large-scale Ti production.
- Perform structural test of unitized multifunctional panel to validate performance of thermal management and load carrying capability over the temperature range of -200 to +200F.
- Produce 1.5 sets of Al based amorphous turbine engine blades that meet print (dimensional) requirements.
- Demonstrate thermal spray technologies and processes at large-scale contractor facility on substrate materials.

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FY 2009 Plans:
- Demonstrate 10x improvement in fracture toughness for Fe based bulk metallic glasses.
- Certify high performance corrosion resistant materials (HPCRM) coatings for unrestricted use on Naval combatants.

	FY 2007	FY 2008	FY 2009
Multifunctional Materials and Structures	15.700	16.000	11.821

(U) The Multifunctional Materials and Structures thrust is developing materials and structures that are explicitly tailored for multiple functions and/or unique mechanical properties. This thrust also explores novel materials that are designed to adapt structural or functional properties to environmental and/or tactical threat conditions. Included in this thrust are efforts that will lower the weight and increase the performance of aircraft, enhance the efficiency of turbines, and improve the survivability of space structures.

(U) Program Plans:

FY 2007 Accomplishments:
- Demonstrated 2X surface hardness in alloy 718 using the low temperature colossal super saturation of Carbon in the atomic lattice.
- Demonstrated ability to control periodic nano features in alumina for warm forming of polymers.
- Designed evaporatively cooled blade configuration of very high thermal efficiency that if applied to current turbine engines would provide significant performance and/or specific fuel consumption benefits.
- Initiated fabrication of a complete set of turbine blades and modified a test bed engine to accept them for engine demonstration.
- Established proof-of-concept that incorporation of circulatory systems into materials can modulate electromagnetic, functional and mechanical properties.

FY 2008 Plans:
- Demonstrate superhydrophobic surfaces up to $1m^2$.
- Integrate solar power collection/thin film battery storage device with collection efficiencies greater than 20% and power output 100X that of state-of-the-art thin film batteries (5 in x 5 in minimum).
- Demonstrate cavitation resistant alloys for use on combat ship propulsors.
- Run test engine with evaporative cooled blades and quantify performance benefits.

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– Initiate development of material systems whose physical, chemical, electromagnetic, or mechanical properties can be modified upon command or in response to environmental stimuli.

FY 2009 Plans:

– Demonstrate functional prototype integrated flexible solar collection array/thin film battery (5 in x 5 in minimum).
– Demonstrate surface wave and power transmission control; point to point communications with less than 1 dB power loss over $1m^2$.
– Predict performance for an operational engine derived from the prototype unit.
– Develop prototype materials whose physical, chemical, electromagnetic, or mechanical properties can be modified upon command or in response to environmental stimuli.

	FY 2007	FY 2008	FY 2009
Materials for Force Protection*	12.123	23.219	18.500

*Previously this was part of Multifunctional Materials and Structures.

(U) The Materials for Force Protection thrust is developing novel materials and materials systems that will greatly enhance protection against ballistic, blast, and explosively formed projectile (EFP) threats. Included in this thrust are novel topological concepts as well as entirely new structural designs that will afford enhanced protection and functionality, at reduced weight and/or cost.

(U) Program Plans:

FY 2007 Accomplishments:

– Developed opaque armor solutions of classified capability.
– Developed a transparent spinel armor solution of increased capability that is significantly lower weight than current solutions.

FY 2008 Plans:

– Demonstrate ballistic performance with reduced weight as compared with rolled homogeneous armor areal density.
– Integrate high performance armor systems into vehicle platforms in collaboration with the U.S. Army and Marine Corps.
– Reduce the cost of hybrid composite armor systems with high throughput manufacturing techniques and by exploiting the benefits of commercial materials.
– Develop topological armor concepts for explosively formed projectile defeat.

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FY 2009 Plans:
- Develop lightweight armor systems to mitigate and defeat evolving threats, including explosively formed projectiles (EFPs).
- Evaluate topological armor concepts for protection against multiple threats.
- Optimize transparent armor for fragmentation and armor piercing threats.
- Integrate high performance armor systems with enhanced protection against evolving threats, including EFPs, into vehicle platforms in collaboration with the U.S. Army and Marine Corps.
- Demonstrate protective abilities of novel topological armor against explosively formed projectile threats.

	FY 2007	FY 2008	FY 2009
Prognosis	10.669	12.000	1.000

(U) The Prognosis thrust will demonstrate revolutionary, new concepts, physics-based models and advanced interrogation tools to assess damage evolution and predict future performance of the structural materials in defense platforms/systems. Included are demonstrations on Navy and Air Force aircraft structures, and engines for advanced jet aircraft and helicopters. Also included are sensor and model development required to support the damage prediction.

(U) Program Plans:

FY 2007 Accomplishments:
- Signed MOA between DARPA Director and Secretary of the Air Force transitioning engine system prognosis (ESP) module to the USAF.
- Conducted full scale testing on a modern gas turbine engine fan that includes prognosis sensors, transfer functions, and reasoners which will permit operating gas turbine engines with damaged fan and compressor blades to double the current damage limits thus significantly decreasing aircraft engine removal and repair requirements in operational units.
- Demonstrated effectiveness of prognosis technology in the H60 class of helicopter engines and in collaboration with the Navy transitioned elements of prognosis to the fleet.

FY 2008 Plans:
- Demonstrate Structurally Integrated Prognosis System (SIPS) on legacy airframes of EA6B and P3.

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– Demonstrate ESP system on the T700 helicopter engines with specific objective of real time "power available" notification to the pilot.

FY 2009 Plans:

– Complete and provide a functional ESP system applicable to the legacy (F100/F110) fleets that incorporates all physics- and data-driven models, exploits the available sensor packages, and incorporates all local and supervisory reasoners interfaced to the aircraft DEEC/MDEC for Oklahoma City Air Logistics Center (OC-ALC). Transition to Air Force Materiel Command.

	FY 2007	FY 2008	FY 2009
Materials for Initiation and Actuation*	4.561	7.234	5.929

*Previously this was part of Smart Materials.

(U) The Materials for Initiation and Actuation program explores and develops materials for initiation and propagation of mechanical and/or chemical effects. Included efforts are bio-inspired structures for meso-scale electrically initiated combustion, cyclic chemical reactions for communication, and high power, low volume, actuators required for high efficiency mobile platforms.

(U) Program Plans:

FY 2007 Accomplishments:

– Demonstrated 1,000 cycles for a combustion-recombinant based actuator.

FY 2008 Plans:

– Develop chemical systems that are able to encode arbitrary alphanumeric messages and transmit them as modulated optical signals at stand-off distances.
– Perform laboratory testing of modulated chemical systems to assess transmission properties including range.
– Demonstrate spanwise blade twisting on a representative rotor set.
– Fabricate, test, and assess silent maneuver capability of a nastic skin array on a scale model submersible.

FY 2009 Plans:

– Refine chemical systems to achieve 100-fold increase in transmission duration.

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- Engineer prototype chemical communications devices consisting of a disposable transmitter and a replicator device, with the form factor of a personal digital assistant, that translates messages into chemistry.
- Conduct rotor stand test of fully actuated 1/3 scale proprotor to demonstrate blade synchronization and lift improvement.
- Initiate development of a reactive structure in which the energetic and structural functions are integrated into the same material.

	FY 2007	FY 2008	FY 2009
Reconfigurable Structures	6.917	8.000	9.571

(U) In the Reconfigurable Structures thrust, 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. This includes the demonstration of a morphing aircraft as well as new materials and devices that will enable the military to function more effectively in the urban theater of operations.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed first prototype of rapidly deployable and reversible, portable barriers to control enemy mobility in urban areas such as intersections, alleyways, doorways, etc.
- Developed model to analyze and reduce stresses due at the corners of contact pads to enable lower attachment pressures and increase adhesion to multiple surfaces.
- Determined the asperity (surface roughness) size distribution across multiple surfaces of interest and developed model to determine the most efficient pattern for asperity matching across said surfaces to ensure adhesion.
- Demonstrated >100 cycles of dry nanoadhesion to glass at approx 30 psi (normal).
- Developed, designed, and tested the actuators, materials, and control architectures necessary for achieving precise shape change in an airframe.
- Demonstrated capabilities of morphing aircraft technology in flight test achieving morphing initiated maneuver, improved turn rate, and improved climb rates between different morphed configurations.

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FY 2008 Plans:
- Develop soft chemically based materials with the ability to drastically change shape, reconfigure, and perform function.
- Engineer soft components from these materials that enable locomotion and size/shape morphing.
- Demonstrate adhesion repeated 100 times on glass, aluminum, and brick under both wet and dry conditions on a 4 inch by 4 inch pad.
- Determine proper climbing techniques via biomechanical analysis for maximum rate of climb, moving laterally, and descending using the required attachment-removal-reattachment kinematics.

FY 2009 Plans:
- Engineer materials and soft components into robotic architecture with the ability to locomote, traverse openings smaller than the characteristic dimension of the robot, reconstitute size/shape, and perform work using embedded payloads.
- Perform laboratory demonstrations of robot function.
- Refine and finalize pad designs for hands and feet based upon results of biomechanical analysis and human climbing trials.
- Demonstrate an equipped soldier (300 lb) scaling a series of 20 ft walls built from relevant materials.
- Develop a new class of synthetic materials whose structure/properties adapt to changing external conditions, using means intrinsic to the material.

	FY 2007	FY 2008	FY 2009
Functional Materials and Devices	14.500	13.399	16.200

(U) The goal of this thrust is to design material microstructures at the scale appropriate to exploit fundamental interactions with the environment in order to create materials with unique properties. Examples include engineered materials (metamaterials) that provide dramatically new electromagnetic behavior across the complete array of Defense applications. Other efforts include nanostructured materials to slow light, negative refractive index systems, and an array of other functional devices (antennas, dosimeters, etc.).

(U) Program Plans:

FY 2007 Accomplishments:
- Demonstrated a novel metamaterial dielectric with unprecedented properties for RF signal identification and tracking.
- Demonstrated novel thick film negative index materials at 20 GHz.

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- Demonstrated sub wavelength focusing at optical wavelengths.
- Demonstrated interleaving of 10 GigaBytes per second (GB/s) data streams using slow-light based tunable delay line.
- Demonstrated slowing of entire image using slow light tunable delay line.

FY 2008 Plans:

- Initiate parametric studies to define the accessible range of activity in surface/environment interactions.
- Design an optical negative index material based modulator for improved optical communications.
- Design a sub wavelength UHF antenna.
- Demonstrate delay of 10 GB/s data stream by more than 75 ns, and incorporate tunable delay into reconfigurable time-based multiplexer.

FY 2009 Plans:

- Design and develop modeling algorithms for surface/environment interactions.
- Demonstrate a low loss, negative index enabled optical modulator with enhanced performance for military communications.
- Demonstrate a subwavelength UHF antenna with enhanced performance for military radar and communication applications.
- Demonstrate delay of 40 GB/s data stream by more than 1 micro-second, and incorporate tunable delay into reconfigurable optical data buffer.
- Develop materials to create an underwater mission system that eliminates the need to carry a primary oxygen supply.

	FY 2007	FY 2008	FY 2009
Power Components*	7.332	12.000	10.500

*Previously this was part of Functional Materials and Devices and Materials for Power.

(U) This thrust explores and develops novel components for use in diverse power systems that will dramatically increase the overall energy efficiency, typically with a substantial savings of weight/volume as well as cost. Included in this thrust are new permanent magnetic materials with significantly higher magnetic strength and higher operating temperature for motors and generators, as well as high energy density capacitors. Hybrid superconducting/cryogenic components, which will provide a new paradigm for power electronics for the “all electric” platforms of the future. Materials technology is also being developed to enhance power conditioning for large power applications such as Navy ships.

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated a high throughput manufacturing process for 2nd generation high temperature superconducting wires with enhanced current carrying capacity at liquid nitrogen temperatures.
- Demonstrated nano-material architectures that are calculated to significantly improve the energy product of magnets, power density of batteries, and figure of merit for high temperature thermoelectrics.
- Demonstrated two optimized nano-phase mixed oxides for anodes in lithium ion batteries.

FY 2008 Plans:

- Determine magnetostatic coupling mechanisms in large grain (> 1 micron) nanocomposite magnets.
- Develop novel compaction methods for achieving high density bulk nanocomposite magnets with superior properties.
- Demonstrate a lightweight inductor based on newly developed 2nd generation high temperature superconducting wires.
- Develop model to predict performance of the all superconducting motor concept with stator windings fabricated from 2nd generation high temperature superconducting wire.
- Develop new dielectric materials with high permittivity, high breakdown strength and high temperature (>200deg C) and incorporate into high energy dense capacitor able to achieve 20J/cc and 100J.
- Develop nano-structured materials and demonstrate the ability to improve thermal electrics with >30% efficiencies, magnetics (30% improvements), and electrochemical (100% improvements) energy storage and conversion.

FY 2009 Plans:

- Develop a predictive modeling tool for the performance of magnetostatic coupled nanocomposite magnets.
- Verify the fidelity of the nanocomposite magnet modeling tool via experimentation.
- Evaluate the potential for cryogenic power electronics based on 2nd generation high temperature superconducting wires for reducing overall losses in Naval shipboard power systems.
- Innovatively package the 20J/cc dielectrics into capacitors with sensing capabilities to provide reliable high power capacitors of 20J/cc and 400J.
- Integrate nano-structured materials with high efficiencies and energy densities into DoD-relevant systems while maintaining the nano-structures of the materials thus increasing energy capabilities.

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	FY 2007	FY 2008	FY 2009
Novel Power Sources*	12.220	14.700	14.500

*Previously this was part of Materials for Power and Alternate Power Sources.

(U) The Novel Power Sources thrust will explore new materials solutions to enable power to be efficiently generated and controlled. This includes new materials concepts to increase the efficiency and robustness of portable fuel cells as well as the exploitation of nanotechnology to increase the efficiency and lower the weight of batteries. 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. An additional focus is to develop materials to drastically improve the efficiency of low temperature thermoelectric components and develop these components into demonstration systems.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated concepts for highly power-dense, man-portable kilowatt generators that will reduce the logistics burden for the soldier in the field.
- Demonstrated a propane fueled 20 W solid oxide fuel cell capability with energy densities > 7x that of current military batteries.
- Demonstrated a portable JP-8 fueled Stirling engine generator.
- Demonstrated record breaking thermal to electric conversion efficiencies approaching 20%.
- Demonstrated record breaking thermal to electric power densities > 5 W/cm^2.
- Demonstrated novel fuel cell based on liquid tin anode for electrochemically converting JP-8 fuel to electricity.
- Developed a theoretical tool for predicting cathode chemistries with > 3x energy density compared to current batteries.
- Initiated new methods for high efficiency non-sacrificial catalysts to reduce carbon dioxide to carbon monoxide for conversion to liquid fuel.

FY 2008 Plans:

- Demonstrate the advantages of fuel cell and Stirling engine generators for enabling longer duration UAV, UGV, and soldier portable applications in relevant military environments.
- Demonstrate “proof of concept” for hybrid electronics enabled high efficiency, high density power electronics for military platforms.

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- Scale up current thermal to electric conversion generators to > 100 W.
- Scale up and integrate JP-8 fuel cell components into a 4 cell stack.
- Develop catalysts for reducing carbon dioxide with sunlight.
- Identify other chemical reactions necessary for liquid fuel systems.
- Design strategy for the conversion of carbon dioxide to JP-8.
- Demonstrate proof of concept for high energy density batteries using newly developed nanostructured cathode and anode materials.

FY 2009 Plans:

- Demonstrate high energy density power sources that enable UAV and UGV mission durations that are >5x longer than current state of the art batteries allow.
- Demonstrate a fully ruggedized (MIL-STD environmental factors) JP-8 fueled battery charger for next generation military rechargeable batteries.
- Provide a military relevant prototype demonstration of the weight and volume savings achievable using a hybrid approach for military efficiency power electronics.
- Conduct a full scale demonstration of a 1 kW or greater thermal to electric generator with record efficiencies and power densities.
- Demonstrate proof of concept for a novel fuel cell chemistry that operates at low to moderate temperatures but exhibits the higher power density, reduced balance of plant complexity, and fuel flexibility of higher temperature solid oxide fuel cells.
- Transition JP-8 fuel cell technology to Services for further development.
- Demonstrate 50% efficiency in the reduction of carbon dioxide to a carbon intermediate.
- Provide a full scale demonstration of a high energy density, high power density nanostructured battery.
- Investigate scaling of potential catalysis approaches for personal, small unit, and mobile power facility fuel cell applications.
- Optimize catalyst performance over a broad range of potential fuels including, but not limited to, ethanol, butanol, and JP-8.
- Develop second generation catalyst approaches and corresponding fuel cell designs to expand the range of operable fuels and scale down system size to personal or small unit scale.

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	FY 2007	FY 2008	FY 2009
Very High Efficiency Solar Cell (VHESC)*	8.000	17.500	21.000

*Previously this was part of Materials for Power.

(U) The objective of the Very High Efficiency Solar Cell (VHESC) program is to demonstrate at least 50% efficiency in an affordable, manufacturable photovoltaic (PV) device. This technology breakthrough will provide soldiers with portable power for electronic devices resulting in a dramatic reduction in the complex logistics associated with delivering batteries to troops in the field, while improving mission endurance and individual soldier agility.

(U) The program addresses all aspects of the high-efficiency PV problem including the development and analysis of high efficiency design concepts, the development of new and innovative components, materials, and processes necessary to achieve these concepts, and the development of scalable fabrication processes that are extensible to industrial manufacturing and an affordable product. Breakthrough results achieved in previous program phases including lateral architectures and non-imaging optical systems, high performance multi-band PV conversion, and ultra-low-cost PV materials fabrication processes have strongly narrowed the focus of the effort going forward. Future program phases will address both the technology development and manufacturing concept and engineering development necessary for the effective implementation of the VHESC technology in an affordable product. The key focus areas of these next two phases will be: 1) the system-integrated design optimization of the non-imaging lateral optics subsystem and the corresponding photovoltaic devices and 2) the development of high-volume cost-effective manufacturing engineering designs and processes for the subsequent future transition to affordable production.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated greater efficiency of solar cell optics and converter technologies in high, mid, and low energy photon environments.
- Developed novel concepts for extremely high efficient solar cells (>50%) and novel solar cell configurations for battlefield deployment.
- Demonstrated optical elements design with > 90% optical efficiency.
- Demonstrated solar cell device efficiency >40%.

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FY 2008 Plans:
- Demonstrate integrated prototype module > 40% efficiency.
- Demonstrate potential cost reduction technologies supporting cost scaling in large scale production.

FY 2009 Plans:
- Deliver initial product designs and production processes for >40% efficient modules.
- Demonstrate integrated system efficiency >50% in 10cm^2 prototypes.
- Deliver an initial integrated soldier systems device (e.g. flashlight or radio with integral solar cell).

	FY 2007	FY 2008	FY 2009
Alternate Power Sources	13.980	13.000	6.000

(U) The aim of the Alternate Power Sources thrust is to develop materials and technologies to utilize alternative power sources that have the potential to provide significant strategic and tactical advantages to the Department of Defense. The thrust is very diverse, and includes the development of diverse, portable power platforms that efficiently (>90%) utilize military waste materials (plastic and paper) for generation of electricity, as well as the development of agricultural plastics that are optimum for electricity generation in these platforms. An additional thrust aims to autonomously extract hydrocarbons such as methane hydrates from the continental shelves, using unmanned drilling and energy recovery vehicles.

(U) Program Plans:

FY 2007 Accomplishments:
- Completed independent evaluation of recently reported experimental protocol for achieving “excess heat” conditions in Pd cathodes loaded with deuterium.
- Integrated new battery and fuel cell chemistries and architectures to fabricate microbatteries with energy densities greater than 200 Wh/L, breaking current state-of-the-art energy densities in volumes smaller than 10 cubic millimeters.
- Completed design for neutron generator with a rate of 10 million per second in a pyroelectric crystal enabled-device.
- Demonstrated directional neutron generation in laboratory scale device.
- Demonstrated depolymerization of mixed plastic into simple hydrocarbon gases by supercritical water.

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- Demonstrated pilot-scale Mobile Integrated Sustainable Energy Recovery (MISER) process for converting waste to 5 kilowatts electric power.
- Demonstrated overall system efficiency of MISER process equal to 70%.
- Demonstrated lab-scale synthesis (0.1g/L/hr) of new bio-based monomer and conversion to high molecular weight polymer with high energy recoverability for future packaging applications.

FY 2008 Plans:

- Develop plan to reduce the volume of the packaged battery and fuel cell to 1 cubic millimeter, while maintaining an energy density of 200 Wh/L.
- Scale up 5 kW MISER process to 60 kW electric generator and demonstrate at a military base.
- Demonstrate efficiency of 90% in MISER system installation.
- Demonstrate use of mixed plastics and paper as fuel for MISER system.
- Improve synthesis (0.5g/L/hr) and polymerization processes for high energy recoverability polymers.
- Determine the correlation between excess heat observations and production of nuclear by-products.

FY 2009 Plans:

- Further improve packaging and architectures to reach final energy density goals of greater than 350 Wh/L, in a volume less than 1 cubic millimeter.
- Demonstrate conversion of bio-based monomer to polymer in 8 hours and conversion of polymer to bio-fuel in 24 hours.
- Demonstrate autonomous cutter head replacement and wellbore measurement for the extraction of hydrocarbons concept.
- Perform system energy analysis including modeling and assessment of scaling limits for the extraction of hydrocarbons concept.

	FY 2007	FY 2008	FY 2009
Biofuels*	3.000	6.500	8.000

*Previously this was part of Alternate Power Sources.

(U) The Biofuels program is exploring longer term, higher risk approaches to obtaining and using energy. A pathway to affordable self-sustainable agriculture-sourced production of an alternative to petroleum-derived JP-8 that will meet all DoD needs will be investigated. Initial efforts are focused on the conversion of crop oil triglycerides to JP-8. Additional efforts will expand the spectrum of convertible feedstocks to

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cellulosic, algal, and other similar materials, enabling a diversified feedstock portfolio that can meet the entire DoD need within a sustainable commercial framework. An important variant of this latter category is the development of man- and vehicle-portable technologies to produce substantial quantities of JP-8 and other useful liquid fuels from indigenously available or harvestable resources near desired locations worldwide.

(U) Program Plans:

FY 2007 Accomplishments:

- Selected a diverse set of technological development pathways to achieve a 60% (or greater) conversion efficiency, by energy content, of crop oil to JP-8 surrogate and elucidate a path to 90% conversion.
- Identified an alternative potential pathway for the production of affordable JP-8 fuel from the seed and grain husk remnants resulting from oil seed and grain seed processing.

FY 2008 Plans:

- Design, develop, and demonstrate a process pathway for >60% conversion (by energy) of crop oil to JP-8.
- Elucidate a path to 90% conversion of crop oil to JP-8.
- Demonstrate the scalability of production technologies for the affordable conversion of crop oil to JP-8 at <$5/gal cost.
- Identify and select technology pathways for the conversion of a broad diversity of cellulosic, algal, and other similar feedstocks to affordable bulk quantities of JP-8.
- Identify and select technology pathways for the development of man- and vehicle-portable systems capable of producing JP-8 and other useful liquid fuels from a broad diversity of feedstocks.

FY 2009 Plans:

- Demonstrate the conversion of cellulosic materials to JP-8 range alkanes with >30% efficiency (by energy).
- Identify a pathway for the conversion of cellulosic materials to JP-8 range alkanes with >50% efficiency (by energy).
- Explore the size and volume efficiency scaling relationships for various processing technologies for converting indigenous materials to JP-8 and other liquid fuels.
- Develop preliminary designs for vehicle-portable and man-portable liquid fuel production systems.

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	FY 2007	FY 2008	FY 2009
Long Duration Power Concepts	8.500	11.000	9.000

(U) The requirement for generating power over long duration missions proposes unique challenges in energy storage, power conditioning and overall integration. This thrust is exploring the breakthroughs in power generation needed for extremely long duration, unmanned applications including unmanned underwater vehicles (UUVs) and unmanned air vehicles (UAVs). These include energy storage approaches that are structurally efficient as well as energy efficient. It also includes approaches for efficiently removing the energy at rates commensurate with the high sprint power often required in these applications.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated an engineering concept based on solid oxide fuel cell and rechargeable batteries for enabling a 30 day large scale UUV mission.
- Demonstrated fuel cell with energy density required to achieve mission set.
- Demonstrated 3x enhancement of carbon fuel cell power output.
- Developed multifunctional material concept for UUV fuel storage.

FY 2008 Plans:

- Demonstrate breadboard UUV power system capable of enabling a 30 day large scale UUV mission.

FY 2009 Plans:

- Full scale laboratory demonstration of solid oxide fuel cell/battery power system for a 30 day large scale UUV mission.

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	FY 2007	FY 2008	FY 2009
Strategic Materials	4.000	5.000	0.000

(U) Program Plans:
FY 2007 Accomplishments:
- Developed reliable, robust, repeatable, and cost effective Chemical Vapor Composite (CVC) SiC manufacturing process for high tech military, space, and industrial applications.

FY 2008 Plans:
- Optimize the process for reliable, robust, repeatable, and cost effective CVC SiC manufacturing process for high tech military, space, and industrial applications.

	FY 2007	FY 2008	FY 2009
Economic Production of Coal-to-Liquid Fuels	0.000	2.400	0.000

(U) This program will research the economic production of converting coal fuels to liquid fuels.

(U) Program Plans:
FY 2008 Plans:
- Research the economic production of converting coal fuels to liquid fuels.

	FY 2007	FY 2008	FY 2009
Reduce Environmental Impact of Coal-to-Liquid Fuels	0.000	2.400	0.000

(U) This program will research ways to reduce the environmental impact of converting coal fuels to liquid fuels.

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(U) Program Plans:
FY 2008 Plans:
– Research ways to reduce the environmental impact of converting coal fuels to liquid fuels.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Biologically Based Materials and Devices MBT-02	125.751	110.590	131.106	106.366	94.438	94.438	94.437

(U) Mission Description:

(U) This project acknowledges the growing and pervasive influence of the biological sciences on the development of new DoD capabilities. This influence extends throughout the development of new materials, devices and processes, and relies on the integration of biological breakthroughs with those in engineering and the physical sciences. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the use of biology's unique fabrication capabilities to produce structures that cannot be made any other way, the application of magnetic materials in biological applications, and the development of manufacturing tools that use biological components and processes for materials synthesis. This project also includes major efforts aimed at integrating biological and digital sensing methodologies and maintaining human combat performance despite the extraordinary stressors of combat. Finally, this thrust will develop new diagnostics, therapeutics, and procedures to save lives on the battlefield, as well as restore full functional capabilities to combat amputees by developing a revolutionary upper limb prosthetic device.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
BioRobotics and BioMechanics*	25.000	7.000	1.000

*Formerly Bioinspired Locomotion and Sensing.

(U) The BioRobotics and BioMechanics thrust explores approaches to capture biological systems' ability to move and sense, and emulate these in man-made robotic or sensor systems. The effort includes providing robotics with the mobility required to provide support to soldiers in all terrains, including climbing. This thrust also includes efforts to develop bioinspired swimming aids that will increase the speed and reduce the metabolic costs for combat divers, and make current devices (fins) obsolete for most tactical scenarios.

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(U) Program Plans:

FY 2007 Accomplishments:

- Developed bioinspired flow sensors (based on fish lateral lines) with a velocity sensitivity 10x better than current state-of-the-art sensors.
- Demonstrated velocity sensitivity better than .01m/sec and an angular resolution of $<5^{o}$ (over 360^{o}).
- Completed modeling of the Melanophila beetles' infrared sensilla organ including photomechanics, microfluidics and microhydraulics.
- Designed, built and tested oscillating foil devices (OFDs), which decreased the metabolic cost of swimming 1km by 50%.
- Finalized the functional geometry of the OFD in a rebreather compatible configuration.
- Developed revolutionary processing approach for fabricating polymer gradient index (GRIN) lenses of almost any size. This technique allows the tailoring of the refractive index profiles in the radial direction as well as along the optical axis in a GRIN lens.
- Achieved GRIN lens Index variations of .12.
- Built and demonstrated a foveated vision system (120 degrees field of view) based on a new generation of high-birefringence liquid crystal (having an index change of >.6) spatial light modulator.
- Demonstrated tetrapod bio-inspired robot with dynamic stability over unplanned terrain including scree.
- Demonstrated carriage of >30kg load over unplanned terrain by tetrapod robot.
- Demonstrated vertical climbing bioinspired robot in both urban and forest environments.
- Signed transition MOA with USMC for tactical tetrapod robot.

FY 2008 Plans:

- Design folding OFDs with 0.5 ft^3 packed volume. Perform simulated missions with OFD devices with elements of the Army, Navy, and Marines. Fabrication of sixty OFD units followed by operational validation. Transition to the military user.
- Design and demonstrate a GRIN lens solution for a night vision system operating in the short wave infrared (SWIR) band.
- Design and demonstrate a non-mechanical (adaptive optical) zoom riflescope based on viscous optical polymer lenses. Zoom riflescope will operate between 1x, 2x, 4x and 10x at the push of a button.
- Demonstrate mobility and range capability in a militarily relevant environment by traversing five miles of wooded terrain while following a human lead.
- Demonstrate dynamic climbing on vertical terrestrial features.

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FY 2009 Plans:
- Deliver fully integrated GRIN optical system to the Army Night Vision Laboratory to be incorporated into a light-weight, high-performance SWIR imaging system.
- Deliver and qualify (MilSpec shock/temperature) a non-mechanical zoom riflescope (1x through 10x) to the Army for field evaluation.

	FY 2007	FY 2008	FY 2009
Bioderived Materials	9.856	1.000	0.000

(U) The Bioderived Materials thrust explores the use of biological materials to support diverse Defense missions and/or technologies that enhance the capability of military biological platforms. Examples include the direct use of biological systems (e.g., plants) as sensors or antennas, as well as exploiting the work and energy harvesting capabilities of biological motors. Additional efforts provide sensor, localization, and communication technologies in direct support of military operations.

(U) Program Plans:

FY2007 Accomplishments:
- Demonstrated the utility of biomolecular motors for DNA transcription.
- Investigated the importance of quantum effects in biomotor function, performance and efficiency.
- Developed a biologically integrated stealthy platform for visual and auditory surveillance capabilities.

FY 2008 Plans:
- Demonstrate training of biological platform integrated with GPS, visual and auditory surveillance, in an urban-based environment.

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Bioinspired Sensors*	9.000	11.500	12.900

*Previously part of Bioderived Materials.

(U) The Bioinspired Sensors thrust explores the application of biomimetic principles to materials and devices of interest to the DoD. Specifically, the unique characteristics of biologically derived material 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 understand the mammalian olfactory system and develop a system that performs equal to or better than a canine, in distance and level of chemical detection. Biological hearing systems also provide localization accuracy much better than predicted by simple array theory. Such systems use complex interactions between reflections off the outer ear and finely tuned neural patterns that provide exquisite localization and sensitivity. This effort includes a program to mimic similar reflections and signal processing approaches suitable for small UAVs.

(U) Program Plans:

FY 2007 Accomplishments:

- Initiated a series of bioinspired materials and sensor (e.g., visual, auditory, olfactory, gustatory and tactile) studies to examine unique characteristics/signatures.
- Investigated the applications to improve current sensor technologies, such as:
  - -- Approaches for utilizing bio-derived components from the mammalian olfactory system for the design of novel chemo-sensing systems.
  - -- Prototype vision sensors based on the properties of the mammalian retina for the creation of high dynamic range sensor capabilities, and tactile sensors for novel situational awareness in robotic platforms.

FY 2008 Plans:

- Develop components for a sensitive, but flexible olfactory system built from and inspired by the structure and components of the mammalian olfactory system.
- Develop methods for high throughput generation of odorant molecules of interest and stable expression of receptor proteins in a cell-based system.

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- Complete design review of prototype olfaction system, for a small number of candidate odorant molecules, using cell-based detection.
- Explore the fundamental interaction of loading metals into plants and elevating their conductive properties through injectable solutions.

FY 2009 Plans:

- Develop brassboard system, with emphasis on synthetic cell or non-cellular expression (chip) for detection of relevant odorant molecules.
- Demonstrate rapid production and detection of new odorant molecule not previously expressed in the synthetic system.
- Exploit increased knowledge in biologic sensing architectures to determine relevant opportunities for improved RF sensing techniques.
- Develop new signal processing and waveform design approaches to facilitate improved sensitivity and localization accuracy with less weight and power.
- Study plant morphologies that will produce useful transmit and receive capabilities in a plant antenna.

	FY 2007	FY 2008	FY 2009
Maintaining Combat Performance	11.700	6.500	8.500

(U) The Maintaining Combat Performance thrust utilizes breakthroughs in biology and physiology to sustain the peak physical and cognitive performance of warfighters operating in extreme conditions. Today, warfighters must accomplish their missions despite extraordinary physiologic stress. Examples of these stressors include extremes of temperature (-20°F to 125°F), oxygen deficiency in mountains, personal loads in excess of 100 lbs, dehydration, psychological stress, and even performance of life-sustaining maneuvers following combat injury. Not only must troops maintain optimum physical performance, but also peak cognitive performance, which includes the entire spectrum from personal navigation and target recognition, to complex command and control decisions, and intelligence synthesis. The Maintaining Combat Performance thrust leverages breakthroughs in diverse scientific fields in order to mitigate the effects of harsh combat environments. For example, understanding the natural mechanisms for core body temperature regulation in hibernating mammals has led to a novel, practical approach for soldier cooling, which is now being evaluated by troops in the far forward combat areas. Other examples include fundamental research elucidating the biological mechanisms of

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adaptation to extreme altitude, the molecular correlates of muscle fatigue and psychological stress, and natural resistance to disease through dietary nutrients.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated a safe, natural dietary supplement that prevented post-stress viral illness in humans.
- Demonstrated a novel ketone-based dietary fat substitute that prevents fatigue in experimental models.
- Identified the biochemical mechanism of skeletal muscle fatigue.
- Developed 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).
- Validated approaches for natural interventions and other concepts that restore the cognitive performance capabilities of warfighters during extended periods of sleep deprivation and stress.

FY 2008 Plans:

- Establish biologic mechanism for illness prevention by Quercetin.
- Complete pharmacokinetic and pharmacodynamic studies in humans.
- Complete toxicology evaluation of ketone-based dietary fat substitute.
- Develop a human formulation of ketone-based diet and demonstrate tolerability in humans.
- Implement prototype hand cooling device for light armored vehicles.
- Investigate approaches for mitigating the effects of disrupted circadian cycles including the use of targeted napping, sound or stimulation enhanced slow wave sleep, light modulation and other restorative techniques.
- Identify novel methodologies to reduce fatigue in sleep deprived conditions through brief, restorative sleep and sleep-like experiences.
- Identify genetic indicators of acute mountain sickness and develop approaches to improve cardio-pulmonary function at high altitude.
- Demonstrate high altitude acclimation can be induced by an effector treatment.
- Demonstrate a >40% improvement from preconditioning prior to high altitude exposure in experimental animals.
- Identify ≥ 2 novel biochemical pathways adversely affected by physiological and/or psychological stress.

FY 2009 Plans:

- Demonstrate performance benefits of ketone-based supplement in humans.

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- Develop and test hand-based warming device on SEAL Delivery Vehicles.
- Develop and demonstrate a selective stabilizer of the skeletal muscle sarcoplasmic reticulum calcium channel.
- Demonstrate the direct cognitive benefit of fatigue reduction methodologies on operational task measures.
- Develop prototype technologies that enable operators to experience restorative sleep at any point in their circadian rhythm in the deployed environment.
- Determine the effects of nitric oxide on altitude acclimatization and methods to minimize acute mountain sickness.
- Identify countermeasures that normalize stress-induced biochemical changes.
- Demonstrate functional improvement in experimental models of stress.

	FY 2007	FY 2008	FY 2009
Cognitive Technology Threat Warning System (CT2WS)*	0.000	8.600	15.800

*Previously part of Maintaining Combat Performance.

(U) Recent advances in computational and neural sciences indicate it is possible to push the visual threat detection envelope to enable more response choices for our soldiers than ever before. The objective of the Cognitive Technology Threat Warning System (CT2WS) program is to drive a breakthrough in soldier-portable visual threat warning devices by leveraging discoveries in the disparate technology areas of flat-field, wide-angle optics, large pixel-count digital imagers, visual processing pathways, neurally based target detection signatures and ultra-low power analog-digital hybrid signal processing electronics. This program will lead to the development of prototype soldier-portable digital imaging threat queuing systems capable of effective detection ranges of 1-10 km against dismounts and vehicles. Simultaneously, the system will survey a 120-degree or greater field of view, enabling the warfighter to detect, decide and act on the most advantageous timeline in complex operational environments.

(U) Program Plans:

FY 2008 Plans:

- Initiate system-level preliminary design of a prototype soldier-portable digital imaging visual threat cueing system capable of improving current effective detection ranges while simultaneously surveying wide field of view.

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- Evaluate methodologies for inclusion of wide angle optics, large pixel count digital imagers, cognitive visual processing algorithms, brain-derived target detection signatures and low power analog-digital hybrid electronics.
- Demonstrate single path (20° x 20°) advanced optics on a breadboard system in a field environment consistent with objective performance and package volume.
- Demonstrate composite software system capable of high fidelity threat detection with extremely low false alarm rates.

FY 2009 Plans:

- Develop integrated brassboard designs consistent with desired threat cueing performance with an increased field of view of 120° x 20° while maintaining size, weight and power constraints.
- Demonstrate visual/cognitive algorithm performance for threat detection on operationally significant image streams with probability of detection (>.98) and false alarm rates (<10) in less than thirty seconds of scan time.
- Complete critical design review of bench-integrated prototype system evaluations that demonstrate the capability of the design to meet the objective system program metrics.
- Evaluate device packaging approaches with the knowledge of ruggedization and robustness required for soldier-portable tactical electronic devices.

	FY 2007	FY 2008	FY 2009
Neovision2*	0.000	6.000	9.000

*Previously part of Maintaining Combat Performance.

(U) Biological vision systems have the exquisite ability to recognize, categorize, and learn new objects in fractions of a second. While animals and humans accomplish this seemingly effortlessly and constantly, computational vision systems have, to date, been unable to replicate this feat of biology. The Neovision2 program is pursuing an integrated approach to developing an advanced object recognition capability based on the visual pathways in the mammalian brain. Specifically, this program will develop a cognitive sensor technology with limited size, weight, and power that transforms data from an imaging sensor suite into communicable knowledge for mobile, autonomous surveillance systems. To achieve the vision, the program will utilize advanced device design, signal processing and mathematical techniques across multiple brain regions to revolutionize the field and create a neuromorphic vision system. This effort originated in PE 0601101E, Project BLS-01.

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(U) Program Plans:

FY 2008 Plans:

- Develop, fabricate and complete functional test of a neuromorphic application specific integrated circuit (ASIC) for emulation of mammalian visual pathway functionalities.
- Initiate scaling studies for design of a complete system prototype for biological visual pathway capabilities.
- Demonstrate advanced algorithms for visual pathway functionality (saccade, foveate and basic object recognition) on the ASIC and validate using topological analysis techniques.

FY 2009 Plans:

- Demonstrate a complete breadboard visual pathway emulation of saccade, foveation and object recognition with visual inputs, neuromorphic processing and natural language outputs in real time.
- Design a second generation application specific integrated circuit (ASIC) with increased functionality for the emulation of all nodes within the mammalian visual pathway (retina through higher cortex).
- Incorporate further refinements and developments of visual pathway algorithms and neuromorphic hardware into brassboard design for production and testing.

	FY 2007	FY 2008	FY 2009
Tactical Biomedical Technologies	19.895	16.950	18.756

(U) The Tactical Biomedical Technologies thrust will develop new approaches to deliver life-saving medical care on the battlefield, as well as novel technologies for reconstruction and rehabilitation of severely injured warfighters. Implicit in this thrust is the fact that there are unique, warfighter-specific challenges in acute and chronic treatment that are not addressed by civilian research and development. Today, more than half of American battlefield fatalities are due to hemorrhage, particularly due to improvised explosive devices (IEDs). To prevent these deaths, there is an urgent need for technologies that enable relatively unskilled personnel (battlefield medics) to diagnose and treat injuries, including the ability to locate and coagulate non-compressible deep bleeders in the thorax or abdomen. Other critical needs stem from the fact that warfighters are frequently victims of blasts, causing patterns of brain, burn, and orthopedic injuries not seen in civilian medical practice. As such, there is a unique military need to develop systems for pain control that are safe even in medically unmonitored environments, such as an active battlefield.

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Once lives are saved, there is an unmet need for new methods to restore function, for example, by restoring long segments of bone that were lost due to blast fragmentation. Development of a transportable magnetic resonance imager (MRI) that is an order of magnitude smaller in volume and weight than current technologies will greatly improve battlefield care. The results of this program will greatly enhance our ability to save lives on the battlefield and provide restoration of normal function to survivors.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed an ultrasound transducer cuff and modeled device performance and biophysical parameters.
- Demonstrated ultrasound detection, localization and coagulation of a simulated deep bleeder in an *in-vitro* testbed.
- Down selected approaches for biomarker control of drug release.
- Manufactured prototype simplified automated ventilator portable ventilators in order to provide emergency respiratory support to far forward personnel.
- Miniaturized first generation portable ventilators and implemented autonomous flow control; extended duty-cycle and improved ease of use.
- Demonstrated 75% group survival without fluid resuscitation after 60% total blood volume hemorrhage.

FY 2008 Plans:

- Develop and test algorithms for bleeder detection, localization, coagulation, and cuff control; integrate into a complete system.
- Conduct in vivo and in vitro experiments to determine the effect of physiological variables on the deep bleeder acoustic coagulation (DBAC) algorithm.
- Demonstrate efficacy of freeze-dried platelet hemostatic agent in pre-clinical models.
- In collaboration with the Navy, conduct clinical studies of freeze-dried platelet in humans.
- Demonstrate an in vitro delivery system that releases a therapeutic dose of a pain drug based on a chosen biological signal and that the release of the drug can be “shut off” when a biomarker for toxic effect is present.
- Initiate in vivo studies of the drug delivery system in live experimental models.
- Finalize good laboratory practices models required for animal rule approval by the FDA.
- Complete studies and reports required for pre-investigational new drug evaluations.
- Determine optimum contrast mechanisms for very low field MRI brain images.

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– Determine method to assess intra-cranial pressure using MRI system.

FY 2009 Plans:

– Develop a fieldable prototype DBAC system that is automated and operates on batteries.
– Demonstrate DBAC system is capable of detecting and localizing clinically significant bleeder size, tracking the movement of the site of bleeding despite patient movement, coagulating the bleeder, and determining completion of coagulation without a human decision maker in the loop.
– Demonstrate performance of pharmaceutical delivery system with additional class of drug(s).
– Demonstrate initiation of the full tissue repair process after loss of a multi-tissue structure in a mammal.
– Develop target product profile for clinical transition of injury repair therapeutics.
– Demonstrate a sprayable nano-clot technology with an in vitro burst pressure greater than 95mm Hg without heat generation of greater than 5°C.
– Conduct final review of freeze-dried platelet product and transition to Army and Navy-sponsored clinical trials.
– Design low magnetic field MRI system capable of producing diagnostic-quality brain image.
– Demonstrate efficacy of "surviving blood loss" therapies in a Good Laboratory Practices (GLP) animal model.

	FY 2007	FY 2008	FY 2009
Trauma Pod*	6.000	8.500	10.500

*Previously part of Tactical Biomedical Technologies.

(U) New approaches are necessary to deliver life-saving medical care on the battlefield. Research has demonstrated that several functions that currently take place in an operating room can be automated, such as tool and supply handling. Furthermore, these functions can be conducted faster and more effectively by autonomous machines making it possible to move these functions onto the battlefield. Developing the capability to perform autonomous diagnosis will assist the medic in determining the type and extent of the injury. Innovative procedure modules, imaging and surgical techniques, and a portable tactical platform will allow patient stabilization and provide precious additional time for transport to the combat support hospital.

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(U) Program Plans:

FY 2007 Accomplishments:

- Performed computed tomography scan on human phantom mounted on a life support for trauma and transport stretcher.
- Demonstrated remote surgery on a surgical mannequin through robotic assistance.

FY 2008 Plans:

- Develop and test additional, fully automated surgical techniques including opening of an airway and insertion of an IV.
- Design integrated system capable of treating pneumothorax, internal hemorrhage, and head trauma.
- Demonstrate proof of principle imaging and surgical techniques on human phantoms and animal models.

FY 2009 Plans:

- Integrate imaging and surgical modules into a portable tactical platform and test overall system.
- Demonstrate imaging and automated imaging diagnosis of a tension pneumothorax, intracerebral bleeding, abdominal bleeding, and retroperitoneal bleeding in an animal model.
- Demonstrate surgical techniques of an airway on an anatomical model, and insertion of an IV, relief of tension pneumothorax, and control of internal bleeding on an animal model.
- Demonstrate scalability of system.

	FY 2007	FY 2008	FY 2009
Biological Interfaces*	0.000	2.500	5.000

*Previously part of Tactical Biomedical Technologies.

(U) This thrust area explores and develops biological interfaces between biotic and abiotic materials. Examples include infection prevention/sterilization at the interface between skin and a battlefield medical device (such as a central intraveneous catheter) as well as enhancing the rehabilitation/recovery effectiveness of interfaces between bone and orthopedic stabilization devices.

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(U) Program Plans:

FY 2008 Plans:

- Demonstrate reliable plasma-initiated million-fold reduction in bacterial count and 99.9% inactivation of bacterial spore population on artificial or animal skin surfaces.
- Determine biochemical variables that accelerate bone growth to integrate with mechanical factors.

FY 2009 Plans:

- Design and construct plasma-based catheter capable of bacterial and spore population reduction.
- Determine appropriate control laws for osseous distraction rates and timing based upon the measured quantities.

	FY 2007	FY 2008	FY 2009
Neuroscience Technologies*	5.300	9.500	12.000

*Previously part of Maintaining Combat Performance.

(U) The Neuroscience Technologies thrust leverages recent advances in neurophysiology, neuro-imaging, cognitive science and molecular biology to sustain and protect the cognitive functioning of the warfighter faced with challenging operational conditions. Warfighters experience a wide variety of operational stresses, both mental and physical, that degrade critical cognitive functions such as memory, learning and decision making. Currently, the long-term impact of these stressors on the brain is unknown, both at the molecular and behavioral level. This thrust area will utilize modern neuroscientific techniques to develop quantitative models of this impact and explore mechanisms to protect and restore cognitive functioning following operational stressors. For example, molecular targets for the restoration of long term memory using micro-ribonucleic acids (mi-RNA) will be tested in animal models for their efficacy following stress and training. This project will also investigate the integration of recently-characterized properties of human brain function and real-time signal processing to enable rapid triage of target-containing imagery. This thrust area will have far-reaching implications for both current and future military operations, with the potential to protect warfighter cognitive performance both prior to and during deployment.

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated that neural signals can be used to significantly (300-500%) improve throughput in visual analysis tasks such as imagery analysis, as compared to using an individual's visuomotor transformation (i.e., movement) based response.
- Identified robust neural signatures for visually salient objects in operationally relevant imagery.

FY 2008 Plans:

- Demonstrate a 10x improvement in long term memory performance thirty days after training, using short nucleotide sequences administered in a single animal model prior to training.
- Develop a comprehensive quantitative description of the impact stress has on the brain, including neurophysiological, cognitive and behavioral measures. This includes understanding the processes by which certain individuals are resilient to the negative effects of stress, understanding how to prevent deleterious effects of stress exposure without blocking the biological and behavioral responses necessary for survival.
- Develop both task-specific and task-independent methods and strategies for neurophysiology-based learning acceleration applicable across multiple domains.
- Determine the stability of neural signatures in complex imagery conditions, including imagery sources and target types.
- Initiate controlled operational tests to demonstrate utility of neural signatures in imagery analysis environment to motivate potential transition interest.

FY 2009 Plans:

- Evaluate delivery methods of mixtures of short nucleotide sequences for long-term memory enhancement and demonstrate a 10-fold enhancement in long-term memory with single and multiple training episodes in two animal models for >30 days.
- Demonstrate the elimination of a deleterious stress response in the mammalian brain through pre-treatment with either behavioral training or pharmacologic administration without negatively impacting normal memory and brain function.
- Demonstrate learning acceleration techniques feasible for use across a broad range of individuals and explore the potential for group/team learning paradigms for increased quantity of expertise production.
- Demonstrate significant increase in imagery throughput and analytic product generation on specific operational tasks.
- Develop prototype systems that utilize neural signatures to speed analysis and improve quality and accuracy of imagery exploitation.

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– Initiate transition of technologies and methodologies to operational use, while validating utility of neural signature inputs into imagery workflow.

	FY 2007	FY 2008	FY 2009
Bio-Magnetic Interfacing Concepts (BioMagnetICs) Materials	4.000	0.000	0.000

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

(U) Program Plans:

FY 2007 Accomplishments:

– Demonstrated proof of concept for novel magnetics-based approaches to therapeutics and diagnostics for military personnel.
– Demonstrated proof of concept for portable, magnetics-based DNA and biochemical sensors.
– Demonstrated proof of concept for high sensitivity magnetics based biosensor array and transitioned to the Defense Threat Reduction Agency.

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	FY 2007	FY 2008	FY 2009
Military Medical Imaging*	7.500	6.040	9.000

*Previously part of Tactical Biomedical Technologies.

(U) The Military Medical Imaging thrust will develop medical imaging capabilities to support military missions and operations. Examples include novel technologies to miniaturize and enhance the capabilities and speed of CAT scanners and to develop non-invasive imaging modalities for use by medics. The emergence of advanced medical imaging allows us to appreciate newly recognized physical properties of biological tissue, or metabolic pathway, or physiological function in order to map it into an image of diagnostic utility and performance. This need is ever increasing as we seek to better understand anatomical, functional and cellular level interactions. The advanced development of these tools will provide a formidable arsenal of diagnostic tools for warfighter performance and care.

(U) Program Plans:

FY 2007 Accomplishments:

- Determined cause of fatal injuries and provided assessments of vulnerabilities and recommendations for enhancements to current protective gear.
- Validated virtual data with data from actual procedures for virtual autopsy.
- Initiated development of relational database for image queries for virtual autopsy.
- Completed development of a new advanced X-ray detector (Pixel Irradiated Contact (PIC)) which provided X-ray detection at quantum-limited signal-to-noise ratios over a thousandfold dynamic range.
- Built low power, demountable X-ray tube source.
- Demonstrated 3x improvement in photon production compared to conventional source.
- Demonstrated 5x improvement in X-ray vertex angle.
- X-ray source provided 2x yield, cone beam uniformity and 3.75x resolution in z dimension.

FY 2008 Plans:

- Incorporate rapid mission rehearsal thrust technologies with computer-aided forensic methods into after-action review to aid in reconstructing incidents from existing data.

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– Complete development of a new transmission anode X-ray source having 2.5 times higher yield and efficiency than conventional reflection anode X-ray tubes and a 40 degree vertex angle.

FY 2009 Plans:

– Demonstrate that an incident can be fully reverted to initial conditions using only injury and vehicle data.
– Utilize reconstructed scenarios for assessment of "lessons learned" and to gain immediate and relevant tactical battlefield knowledge.
– Develop a new dual-energy transmission anode X-ray source enabling dual-energy, digital-subtraction contrast imaging specifically targeting the detection of occult bleeding in battlefield casualties.

	FY 2007	FY 2008	FY 2009
Revolutionizing Prosthetics	25.000	23.500	24.650

(U) The goal of this thrust is to radically improve the state of the art for upper limb prosthetics, moving them from crude devices with minimal capabilities to fully integrated, fully functional limb replacements. Current prosthetic technology generally provides only gross motor functions, with very crude approaches to control. This makes it difficult for wounded soldiers to return to military service. The advances required to provide fully functional limb replacements will be achieved by an aggressive, milestone driven program combining the talents of scientists from diverse areas including: medicine, neuroscience, orthopedics, engineering, materials science, control and information theory, mathematics, power, manufacturing, rehabilitation, psychology and training. The results of this program will radically improve the ability of combat amputees to return to normal function.

(U) Program Plans:

FY 2007 Accomplishments:

– Constructed and tested three upper extremity limb prototypes incorporating features of advanced control, sensory feedback, and high degrees of articulation.
– Developed control methods using brain/neural activity as well as methods based on natural body movements supplemented by residual limb control.
– Began clinical testing of prototype limbs with amputee populations through surgical and non-surgical control methods.

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FY 2008 Plans:
- Perform testing and evaluation required for initiation of clinical trials.
- Design and manufacture prototype limb including biomimetic articulation, longevity of power consumption, and strength and weight which emulate form, function, and response of natural biological limbs.
- Develop and demonstrate a clinical prototype virtual integration environment.
- Initiate clinical testing of initial limb prototype in combat amputees at military medical centers.
- Develop strategies and technologies for commercial manufacture.

FY 2009 Plans:
- Integrate sensory feedback into prosthetic devices.
- Evaluate sensory feedback in patients with targeted neural re-implantation.
- Complete design of chip for transmission of central nervous system motor signals.
- Evaluate chip in experimental models.
- Demonstrate the ability to implement brain/neural control with sensor feedback in a control architecture that combines the kinetics and mechanics (degrees of freedom) of natural movement, including the realization of proprioception and reflex.
- Develop clinical protocol for testing of four-year prosthetic devices at military medical centers.
- Initiate manufacture plan consistent with Good Manufacturing Practices (GMP).

	FY 2007	FY 2008	FY 2009
Biodemilitarization of Munitions	0.000	3.000	4.000

(U) Based on results from the External Protection Program in PE 0602383E, Project BW-01, the Biodemilitarization of Munitions program will develop a system for rapid, safe, and effective inactivation of explosive munitions stockpiles in place. If these stockpiles can be removed, the raw materials for constructing improvised explosive devices will be greatly reduced. Chemical and biological technologies and control processes will be developed that rapidly perforate munition casings and alter the explosive fill. The perforation and explosive alteration technologies will be integrated into a fieldable system and tested against munitions stockpiles.

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(U) Program Plans:

FY 2008 Plans:

- Investigate technologies for rapidly perforating diverse types of munitions casings.
- Develop mathematical models that describe the perforation and inactivation technologies.
- Investigate technologies for rapidly inactivating diverse types of explosive fill.

FY 2009 Plans:

- Test system against explosive munitions with 155 mm projectiles.
- Develop prototype fieldable system.
- Integrate technologies into a prototype system.
- Test system against munitions stockpiles.

	FY 2007	FY 2008	FY 2009
Bio-Fabrication (B-FAB)	2.500	0.000	0.000

(U) The Bio-Fabrication (B-FAB) program demonstrated the feasibility of using biochemical processes as a new nanofabrication toolset to synthesize and manufacture chemicals, materials, and devices of high value to the DoD. Such approaches would be useful as part of the nanostructure for highly efficient solar cells. Other targets for demonstration within this program included scalable technologies for opto-electronic materials and devices, mechanical materials, and site-directed-synthesis.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed bio-enabled routes for the fabrication of relevant electronic, optical, or structural materials.
- Demonstrated the essential capacity for the fabrication of the materials at the scale of interest (2-20nm range control).
- Demonstrated the capability to produce bio-fabricated materials with chemically and spatially modulated properties.
- Designed, developed, and integrated bio-fabricated optical devices with improved cost characteristics.

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(U) Other Program Funding Summary Cost:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY: RDT&E, Defense-wide; BA2 Applied Research			R-1 ITEM NOMENCLATURE: Electronics Technology; PE 0602716E, Project ELT-01				
COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	215.742	196.707	211.457	229.195	237.767	238.162	248.066
Electronics Technology ELT-01	215.742	196.707	211.457	229.195	237.767	238.162	248.066

(U) Mission Description:

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

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

(U) The phenomenal progress in current electronics and computer chips will face the fundamental limits of silicon technology in the early 21st century, a barrier that must be overcome in order for progress to continue. Another thrust of the program element will explore alternatives to silicon-based electronics in the areas of new electronic devices, new architectures to use them, new software to program the systems, and new methods to fabricate the chips. Approaches include nanotechnology, nanoelectronics, molecular electronics, spin-based electronics, quantum-computing, new circuit architectures optimizing these new devices, and new computer and electronic systems architectures. Projects will investigate the feasibility, design, and development of powerful information technology devices and systems using approaches to electronic device designs that extend beyond traditional Complementary Metal Oxide Semiconductor (CMOS) scaling, including non silicon-based materials technologies, to achieve low cost, reliable, fast and secure computing, communication, and storage systems. This investigation is aimed at developing new capabilities from promising directions in the design of information processing components using both inorganic and organic substrates, designs of components and systems leveraging quantum effects and chaos, and innovative approaches to computing designs

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

- Electronics: The manipulation of electrons in digital, analog, and mixed signal circuits for sensing, processing, and communications. This thrust includes such programs as Advanced Microsystems Technology Program; Applications of Molecular Electronics (MoleApps); High Frequency Wide Band Gap Semiconductor Electronics Technology; High Power Wide Band Gap Semiconductor Electronics Technology; J-Band Advance Digital Receiver (JADR); Ideal Channel Electronics (ICE); Quantum Information Science (QIS); Robust Integrated Power Electronics (RIPE); Submillimeter Wave Imaging FPA Technology (SWIFT); Technology Efficient Agile Mixed Signal Microsystem (TEAM); Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST); Feedback-Linearized Microwave Amplifiers; Terahertz Imaging Focal-Plane Technology (TIFT); Trusted, Uncompromised Semiconductor Technology (TrUST); Carbon Electronics for RF Applications (CERA); Compound Semiconductor Materials On Silicon (COSMOS); Compact Vacuum Electronic Radio Frequency Technology (COVERT (HiFIVE)); Steep-subthreshold-slope Transistors for Electronics with Extremely-low Power (STEEP); Semiconductor-Tuned HTS Filters for Ultra-Sensitive RF Receivers (SURF); Thz Transistors; and Ultra-low Power Subthreshold Electronics (UPSE).

- Photonics: The generation, detection, and modulation of photons for imaging, communications, and sensing. This thrust encompasses the following programs: Adaptive Focal Plane Arrays (AFPA); Advanced Precision Optical Oscillator (APROPOS); Bio-Electronics and Photonics; Chip-to-Chip Optical Interconnects; Photonic Analog Signal Processing Engines with Reconfigurability (PhASER); Parametric Optical Processes and Systems (POPS); Linear Photonic radio frequency (RF) Front End Technology (PHOR-FRONT); Optical Arbitrary Waveform Generation (OAWG); Transparent Displays; Systems of Neuromorphic Adaptive Plastic Scalable Electronics (SyNAPSE); Technology for Agile Coherent Optical Transmission & Signal Processing (TACOTA); Ultrabeam; Photonic Bandwidth Compression for Instaneous WideBand Analog to Digital (A/D) Conversion; Novel Technologies for Optoelectronics Materials Manufacturing (NTOMM); Optical Antenna Based on Nanowires; Short Range Wide-field-of-regard Extremely-agile Electronically-Steered Photonic Emitter & Receiver (SWEEPER); Ultra Low Loss Photonic Integrated Circuits and Processors; Visible InGan Injection Lasers (VIGIL); Ultra Fast Lasers with Response > 100 GHz; Precision OptoMechanics – Mechanical Properties of light; Raman Beam Combining and Cleanup; Frequency Domain Analog Optical Signal Processor; Receiver Power Optimized for Reconnaissance and Tagging (REPORT); Non-Contact EEG Technologies (NET); and Ultra-low Power Subthreshold Electronics.

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- MicroElectroMechancial Systems (MEMS): Exploitation of the processing tools and materials from semiconductor technology to build electro-mechanical structures at the micro- and nano-scale. The MEMS thrust encompasses: 3-D Microelectromagentic RF Systems (3-D MERFS); Chip Scale Atomic Clock; Radioisotope Micropower Sources (RIMS); and Micro Isotope Micro-Power Sources (MIPS).

- Architectures: Exploitation of new arrangements of materials, devices, and circuits to increase performance or reduce power. Programs under this thrust include: Analog-to-Information (A-to-I); Computational Imaging (CI); Design Tools for 3-Dimensional Electronic Circuit Integration; Multiple Optical Non-Redundant Aperture Generalized Sensors (MONTAGE); Polymorphous Computing Architecture (PCA); Vertically Interconnected Sensor Arrays (VISA); and Structured ASIC Design (StASD).

- Algorithms: Exploitation of insights into mathematical constructs for data representation, process control, and discrimination routines by leveraging knowledge of Microsystem hardware operation. Programs under this thrust include: Cognitively Augmented Design for Quantum Technology (CAD-QT); Design-space Exploration and Synthesis Technology for Integrating nontraditional Microsystems at yield (DESTINY); Non-Linear Math for Mixed Signal Microsystems; Processing Algorithms with Co-design of Electronics (PACE); and Quantum Sensors.

- Other Electronic Technology Research: National Secure Foundry Initiative; Characterization, Reliability and Applications for 3-D Microdevices; and 3-D Technology for Advance Sensor Systems.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Advanced Microsystems Technology Program	5.000	5.000	5.000

(U) The Advanced Microsystems Technology program will explore a range of advanced microsystem concepts well beyond existing current technologies. The program focuses on technologies that exploit 3-dimensional (3-D) structures, new materials for Gieger mode detectors, advance patterning, and extreme scaling in silicon devices. Insights derived in these areas will be exploited in future program initiatives. These initiatives include advanced high-resolution lithography, high speed avalanche devices with response out to 2 micrometers (um); integration of periodic elements III-V material with silicon; and novel cryogenic electronics.

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(U) Program Plans:

FY 2007 Accomplishments:

- Established and exercised multi-project wafer runs for 3-D integrated circuits.
- Demonstrated bonding and functionality of Silicon-On-Insulator circuits to Indium Phosphide detectors.
- Extended maskless multiple exposure system to 2x smaller features.

FY 2008 Plans:

- Demonstrate photoresist capable of multiple in-situ exposure with enhanced resolution.
- Demonstrate sub-35 nanometer (nm) half-pitch interometric liquid exposure capability.

FY 2009 Plans:

- Prepare report analyzing prospects for beyond roadmap technologies.
- Deliver data on ultra-low voltage operation of Silicon CMOS for DoD applications.

	FY 2007	FY 2008	FY 2009
Applications of Molecular Electronics (MoleApps)	3.638	0.000	0.000

(U) The goal of the Applications of Molecular Electronics (MoleApps) program extended the capabilities being developed in the previous Moletronics program to demonstrate the computational processing capabilities of molecular electronics in a system that integrates memory with control logic and data paths. This approach allowed the use of simpler processor designs to demonstrate the advantages of nano-scale molecular electronics that do not have the conventional circuitry overhead associated with modern pipeline chip designs.

(U) Program Plans:

FY 2007 Accomplishments:

- Constructed combinatorial logic functions assembled from molecular-scale components.
- Demonstrated molecular electronics sensor array capable of probability of detection > 0.95 and false positive < 0.01.
- Demonstrated sequential logic, control and Input/Output (I/O) circuit compatible with memory and full computer design.

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	FY 2007	FY 2008	FY 2009
High Frequency Wide Band Gap Semiconductor Electronics Technology	30.711	25.000	25.000

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

(U) Program Plans:

FY 2007 Accomplishments:

- Developed bulk and surface process technologies for reducing or mitigating crystallographic defects in wide bandgap materials.
- Developed semi-insulating substrates for high frequency devices.
- Designed high power enclosures for microwave electronic assemblies.
- Demonstrated large periphery high power devices suitable for microwave and mm-wave operation.
- Demonstrated process reproducibility and minimization of yield limiting factors.
- Established device characterization for very high power solid-state amplifiers.
- Demonstrated 100 mm Silicon Carbide (SiC) and wide band gap alternate substrates with less than 80 micropipe/cm^2 and resistivity 10^6 ohms-cm.

FY 2008 Plans:

- Demonstrate epitaxial processes that yield + 3% 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^2 and resistivity 10^7 ohms-cm.
- Demonstrate epitaxial processes that yield + 1% uniformity over 100 mm wide bandgap substrates.
- Identify fabrication processes for robust microwave and mm-wave devices.

FY 2009 Plans:

- Identify thermal management concepts to sustain more than 1 KW/cm^2 power density in high-power devices.

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

	FY 2007	FY 2008	FY 2009
High Power Wide Band Gap Semiconductor Electronics Technology	10.500	1.500	1.000

(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 bandgap semiconductors.

(U) Program Plans:

FY 2007 Accomplishments:
- Developed low defect conducting Silicon Carbide (SiC) substrate consistent with yielding 1 cm^2 devices.
- Developed lightly doped, thick (more than 100 micron) SiC epitaxy with low defects to enable 10 kV class power devices.
- Developed low on-state resistance SiC diodes capable of blocking 10 kV.
- Demonstrated SiC wafer and thick epitaxy with less than 1.5 catastrophic defects per cm^2 consistent with 10 kV reverse blocking.
- Initiated work on Megawatt class SiC power device able to switch at more then 100 kHz.
- Initiated work on packaging of high power density, high temperature SiC power electronics.

FY 2008 Plans:
- Demonstrate megawatt Class SiC power devices.
- Demonstrate high power density packaging for greater than 10 kV operations.

FY 2009 Plans:
- Develop integrated power control logic compatible with high temperature and power SiC power devices.

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	FY 2007	FY 2008	FY 2009
Quantum Information Science (QIS)	8.240	4.240	3.350

(U) The Quantum Information Science (QIS) program will explore all facets of the research necessary to create new technologies based on quantum information science. Research in this area has the ultimate goal of demonstrating the potentially significant advantages of quantum mechanical effects in communication and computing. Expected applications include: new improved forms of highly secure communication; faster algorithms for optimization in logistics and wargaming; highly precise measurements of time and position on the earth and in space; and new image and signal processing methods for target tracking. Technical challenges include: loss of information due to quantum decoherence; limited communication distance due to signal attenuation; limited selection of algorithms and protocols; and larger numbers of bits. Error correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Signal attenuation will be overcome by exploiting quantum repeaters. New algorithm techniques and complexity analysis will increase the selection of algorithms, as will a focus on signal processing. The QIS program is a broad-based effort that will continue to explore the fundamental open questions, the discovery of novel algorithms, and the theoretical and experimental limitations of quantum processing as well as the construction of efficient implementations.

(U) Program Plans:

FY 2007 Accomplishments:

- Refined quantum architecture and designed solutions for problems such as graph isomorphism, imaging, and signal processing.
- Investigated alternative protocols for secure quantum communication, quantum complexity, and control.
- Integrated improved single and entangled photon sources and detectors into existing quantum communication networks.

FY 2008 Plans:

- Investigate alternative designs, architectures and devices for quantum communication and demonstrate high-rate (1Gbit/sec) quantum-secure communication over a single link.

FY 2009 Plans:

- Investigate unresolved fundamental issues related to quantum information science.
- Employ qubit architectures to demonstrate an application of interest to the DoD (e.g., quantum repeater, secure metropolitan-area network).
- Demonstrate interoperation between multiple qubit types to interconnect quantum communications links.

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	FY 2007	FY 2008	FY 2009
Robust Integrated Power Electronics (RIPE)	8.879	5.753	4.800

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

(U) Program Plans:

FY 2007 Accomplishments:

- Identified key technical challenges and quantified impact on potential platforms.

FY 2008 Plans:

- Perform concept study to define opportunities for smart power and the potential for integrating silicon carbide, or other wide band gap semiconductor, with silicon electronics.
- Select and optimize wide band gap materials and processes for smart power circuits.

FY 2009 Plans:

- 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.

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	FY 2007	FY 2008	FY 2009
Submillimeter Wave Imaging Focal Plane Array (FPA) Technology (SWIFT)	5.116	5.260	0.000

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

(U) Program Plans:
FY 2007 Accomplishments:
– Developed compact, efficient, and high-power THz (terahertz) sources using new electronic and frequency conversion approaches.
FY 2008 Plans:
– Develop sensitive and large format receiver arrays, advanced integration, and backend signal processing techniques.
– Develop and demonstrate a submillimeter focal plane imager.

	FY 2007	FY 2008	FY 2009
Technology Efficient, Agile Mixed Signal Microsystem (TEAM)	5.254	0.000	0.000

(U) Technology for Efficient, Agile Mixed Signal Microsystems (TEAM) explored 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:
FY 2007 Accomplishments:
– Demonstrated several large-scale compelling radio frequency (RF)-technology integrated circuits (ICs):
-- 60 GHz (gigahertz) transceiver.
-- Radar-on-a-chip front end demo (7 – 18 GHz).
-- Electronic warfare receiver (2-18 GHz).

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– Developed enhanced passive components for silicon-germanium (SiGe) RF technology.

	FY 2007	FY 2008	FY 2009
Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST)	8.120	7.420	0.000

(U) The Technology for Frequency Agile Digitally Synthesized Transmitters (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 established 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 is extending 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:

FY 2007 Accomplishments:

– Developed material and processed technology for super-scaled InP double heterostructure bipolar transistors (DHBTs).
– Extended the core DHBT and interconnect technology with the implementation of complex mixed signal circuits.
– Developed super-scaled InP HBT processing technology for 0.25 micron and below.
– Developed greater than 100 gigahertz (GHz) mixed signal circuit building blocks.
– Demonstrated a critical mixed signal building block circuit operating at more than 100 GHz.
– Developed circuit designs for direct digital frequency synthesizers (DDS) operating with clock speed up to 30 GHz.
– Demonstrated world's fastest transistor, frequency divider, and mixed signal circuit.

FY 2008 Plans:

– Develop full circuit capability using super-scaled InP HBTs in complex (more than 20,000 transistor) circuits.
– Establish device models and critical design rules.
– Continue further development of world's fastest InP HBT device technology.

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	FY 2007	FY 2008	FY 2009
Feedback-Linearized Microwave Amplifiers	5.580	4.970	3.840

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

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated record ultra-wideband high-linearity Indium Phosphide (InP) Heterojunction Bipolar Transistor (HBT)-based RF operational amplifier and record InP high electron mobility transistor (HEMT).
- Demonstrated world's first enhancement-mode InP HEMT.
- Demonstrated ultra-high linearity RF amplifiers.

FY 2008 Plans:

- Develop InP HBT-based ultra-high linearity low-noise amplifier circuit architecture and develop low-noise InP HEMT devices.

FY 2009 Plans:

- Develop and enhance InP HBT-based RF operational amplifier and InP HEMT-based ultra-low-noise amplifier.

	FY 2007	FY 2008	FY 2009
Terahertz Imaging Focal-Plane Technology (TIFT)	10.667	10.440	7.000

(U) The Terahertz Imaging Focal-Plane Technology (TIFT) program will demonstrate large, multi-element (> 40K pixels) detector receiver focal plane arrays that respond to radiation in the terahertz (THz) band (> 0.557 THz). The sensor system will be able to operate effectively at a stand-off range (> 25m) with a high spatial resolution (< 2 cm) limited only by beam diffraction. The imaging receiver will produce a two-

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dimensional image in which each pixel records the relative intensity of the THz radiation received on the focal plane within the appropriate section of the field of view of the scene being sensed. The program will achieve intensity sensitivities as close as possible to the thermal background limit at room temperature. The minimal acceptable acquisition time is video-rate (30 Hz (hertz)). The receiver may be either passive or active (including THz time domain methods). The size, weight, and electrical power requirements will be consistent with portability.

(U) Program Plans:

FY 2007 Accomplishments:

– Demonstrated revolutionary component and integration technologies necessary for the development of a diffraction-limited, video-rate THz (at least 0.557×10^{12}Hz) frequency imager.

FY 2008 Plans:

– Demonstrate a compact THz source achieving at least 10 mW of average power and 1% wall plug efficiency, as required for active illumination and/or for local oscillators in heterodyne or homodyne detection schemes.

FY 2009 Plans:

– Demonstrate a THz receiver capable of achieving a noise equivalent power of less than 1 $pW/Hz^{1/2}$ as measured with an integrated acquisition time of no more than 30 milliseconds and a pre-detection bandwidth of no more than 50 GHz (gigahertz), as required in order to achieve a system-level noise equivalent delta temperature of 1K or better.

	FY 2007	FY 2008	FY 2009
Trusted, Uncompromised Semiconductor Technology (TrUST)	12.982	19.817	2.000

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

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(U) Program Plans:

FY 2007 Accomplishments:

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

FY 2008 Plans:

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

FY 2009 Plans:

- Explore Integrated Circuit monitoring for deployed performance verification.

	FY 2007	FY 2008	FY 2009
Carbon Electronics for RF Applications (CERA)*	0.000	4.406	5.000

*Formerly titled Co-integration of Carbon-Based RF Electronics with Silicon Technology (CrEST).

(U) The Carbon Electronics for RF Applications (CERA) program seeks to develop metal oxide silicon field effect transistors based on the planar carbon monolayer (graphene) system. Such a system has most of the desirable properties of carbon nanotubes, but found in a planar geometry, which is much more compatible with standard Complementary Metal-Oxide Semiconductor (CMOS) processing. The 10x mobility enhancement of graphene with respect to silicon will be exploited for high performance (high current drive) and low power electronics applications. The excellent mobility is achieved in a monolayer system, which is ideal from the electrostatic (i.e., gate control) point of view enabling efficient scaling to very small device geometries. Graphene Field-Effect Transistor (FET) devices are envisioned to be an enhancement, not replacement for silicon CMOS, for critical radio frequency or mixed signal circuit elements. Thus, the demonstrated integration of graphene devices into standard silicon CMOS processing is a key task of this program.

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(U) Program Plans:
FY 2008 Plans:
– Demonstrate hybrid graphene-silicon CMOS circuits for high performance and low power applications.
FY 2009 Plans:
– Integrate graphene devices into standard silicon CMOS processing.

	FY 2007	FY 2008	FY 2009
Compound Semiconductor Materials On Silicon (COSMOS)	6.579	6.680	16.040

(U) The objective of the Compound Semiconductor Materials On Silicon (COSMOS) program will be to develop new methods to tightly integrate compound semiconductor technologies within silicon CMOS circuits in order to achieve unprecedented circuit performance levels. Currently, heterogeneous integration of compound semiconductors with silicon is typically achieved through the use of multi-chip modules and similar assemblies. While adequate for relatively low performance applications (e.g., power amplifiers for cellular telephone handsets), the integration complexity that can be achieved in this manner is extremely limited. At the other end of the spectrum, epitaxial methods to grow III-V materials onto silicon substrates have generally proven unsatisfactory due to high defect densities, cost, and inflexibility in supporting multiple technologies. Instead, COSMOS will focus on an intermediate approach, which is likely to be the most successful strategy in terms of performance, size and cost. This will involve sub-circuit integration in which III-V materials devices are placed onto a processed CMOS wafer.

(U) Program Plans:
FY 2007 Accomplishments:
– Demonstrated ultra-low power dissipation circuits.
– Investigated approaches that permit mix-and-match of devices processed either before or after placement.
– Demonstrated device placement and interconnect capabilities.
– Refined and demonstrated an approach for intimate compound semiconductor/CMOS integration.
FY 2008 Plans:
– Develop methods for sub-circuit integration onto fully processed CMOS wafers.
– Develop scalable electro-magnetic (EM), thermal and mechanical models.

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– Estimate thermal and mechanical properties of integration materials and perform thermal and stress modeling to determine and improve the viability of the COSMOS thermal and mechanical design.

FY 2009 Plans:

– Fabricate wafers using the COSMOS process.
– Evaluate alignment and bonding methods to achieve mechanical integrity of dissimilar materials, post-processing compatibility with CMOS, and the achievement of high fabrication yields.
– Extend the capabilities of wide band gap devices for use in power amplifiers (PAs) at frequencies at least as high as X-band and to make this technology useful at very high frequencies.
– Demonstrate large (>1 mm) devices.
– Decrease the number of optical phonons in the critical gate region of radio frequency (RF) PA devices.

	FY 2007	FY 2008	FY 2009
Steep-subthreshold-slope Transistors for Electronics with Extremely-low Power	0.000	8.000	8.730

(U) The Steep-subthreshold-slope Transistors for Electronics with Extremely-low Power (STEEP) program seeks to develop field emission (tunneling) based Metal Oxide Silicon Field Effect Transistors (MOSFETs). Such devices would enable lowering supply voltages by 5x, which would result in an active power savings of 25x and a stand-by power saving of at least 5x. Prototype circuits will be developed showing such power savings with little to no impact on performance (current drive). These field emission devices will be integrated into standard CMOS based processing methods and offer significant CMOS power reduction with no performance penalty.

(U) Program Plans:

FY 2008 Plans:

– Develop novel MOSFET switch with significantly steeper sub-threshold slope.
– Develop CMOS process integration.

FY 2009 Plans:

– Optimize drive current in presence of tunneling barrier.
– Demonstrate ultra-low power, high performance prototype circuits.

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	FY 2007	FY 2008	FY 2009
COmpact Vacuum Electronic Radio-frequency Technology (COVERT) (HiFIVE)	0.000	4.000	5.000

(U) The goal of the Compact Vacuum Electronic Radio-frequency Technology (COVERT) (HiFIVE) program is to demonstrate microfabricated, integrated vacuum tubes operating at 220 gigahertz (GHz) with a minimum of 50 watts of output power and 5 GHz bandwidth. The COVERT program figure of merit will be power bandwidth product, and the goal is to achieve 500 power-bandwidth (W-GHz). The ultimate goal is to develop a micro-fabricated, high-bandwidth, high-power "upper" millimeter-wave (220 GHz) amplifier consisting of an integrated high-power amplifier (HPA) consisting of a solid-state millimeter-wave monolithic integrated circuit (MMIC) driver, an integrated cathode, compression optics, micromachined interaction structure, and beam collector.

(U) Program Plans:

FY 2008 Plans:

– Demonstrate a high aspect ratio beam with required power and transport efficiency.

FY 2009 Plans:

– Validate cold test interaction of structure design and high current density cathode.

	FY 2007	FY 2008	FY 2009
Semiconductor-Tuned HTS Filters for Ultra-Sensitive RF Receivers (SURF)	0.000	4.169	3.213

(U) The operation of frequency-hopping radios greatly interferes with co-located ultra-sensitive receivers. The situation will get worse as the "hoppers" proliferate, even interfering within the receive channels of one another. At present there is no solution to this problem, other than turning off the receivers when communicating. A general solution would be to use "brick-wall" front-end filters for the receivers, re-tuning at the rate of the hoppers, if such agile filters were available. High-temperature superconducting (HTS) filters have been used very successfully for negating strong transmissions at nearby frequencies, and are unique in their ability to totally reject out-of-band signals without attenuation of signals in the pass-band. However, they have been used only for rejection of fixed-frequency interference. The Semiconductor-Tuned HTS Filters for Ultra-Sensitive RF Receivers (SURF) program will increase the tuning speed of HTS filters, from about a second with present mechanical

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methods, to microsecond speeds required for systems such as the Joint Tactical Information Distribution System (JTIDS). The technology for such a million-fold improvement will rely upon semiconductor tuning, properly mated with the superconducting filter materials. In addition to interference-rejection at microsecond speeds, these filters will make it possible to perform wide spectral searches with unprecedented frequency resolution, enabling detection of very weak emissions (signatures) characteristic of threat systems.

(U) Program Plans:

FY 2008 Plans:

- Demonstrate one microsecond switching of HTS filters, between three frequencies.
- Develop models of the high-temperature superconducting (HTS) tunable filters.
- Achieve microsecond stepwise semiconductor switching between three stable states.
- Continue development of low-loss semiconductor tuning elements for HTS filters, operating at cryogenic temperatures.
- Demonstrate stepwise tuning of HTS filters at microsecond increments over a broad tuning range.

FY 2009 Plans:

- Complete the development of reconfigurable filter design tools.
- Demonstrate the operation of continuously tunable notch and passband filters, using cryo-optimized semiconductor and varactor tuning elements.

	FY 2007	FY 2008	FY 2009
Adaptive Focal Plane Arrays (AFPA)	4.000	2.870	1.275

(U) The goal of the Adaptive Focal Plane Arrays (AFPA) 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 IR bands), thus enabling "hyperspectral imaging on a chip." This 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:
FY 2007 Accomplishments:
– Developed component technology (tunable IR photodetectors).
FY 2008 Plans:
– Integrate detector array.
– Demonstrate pixel-by-pixel electrical tunability in IR.
FY 2009 Plans:
– Demonstrate AFPA prototype field using a large format array.

	FY 2007	FY 2008	FY 2009
Advanced Precision Optical Oscillator (APROPOS)	6.020	2.200	0.000

(U) The Advanced Precision Optical Oscillator (APROPOS) program will leverage advances in materials and lasers to develop new precision microwave-stable local oscillators with extremely low phase noise (up to 50 decibels better than the current state of the art) at small offsets from microwave carrier frequencies. This capability will enhance performance of radars in the detection of slow moving targets, electronic warfare systems in the identification of specific emitters, and communication systems in weak signal detection and clutter suppression all at increased stand-off range.

(U) Program Plans:
FY 2007 Accomplishments:
– Demonstrated first opto-electronic oscillator without any electronic radio frequency (RF) amplifier.
– Demonstrated 10 gigahertz RF Optical Oscillator that outperforms any existing RF oscillator at 1 hertz to 10 kilohertz frequency offsets.
– Demonstrated tunable Opto-Electronic Oscillator with phase noise performance 20 decibels better than best synthesizer alternative.
FY 2008 Plans:
– Develop an opto-electronic oscillator with ultra low phase noise, tunable oscillator range, and vibration sensitivity.

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	FY 2007	FY 2008	FY 2009
Bio-Electronics and Photonics	4.000	5.000	0.000

(U) The Bio-Electronics and Photonics program will demonstrate new capabilities in biologically derived optical and electronic media and devices. The thrust will explore highly promising organic and biological materials, such as Deoxyribonucleic Acid (DNA), proteins and novel nucleic acid-like materials that have the potential to fundamentally change the way that we develop and process electronics. The novel use of these materials has the potential to produce the biological analog of band gap and heterostructure engineering. This program will develop techniques for inclusion of such biological materials in a myriad of electrical devices ranging from diodes to batteries. The primary objective of this program is toward improved performance and lower costs. Examples of improved device performance would be reduced leakage current and faster switching times in field effect transistors, two areas that have shown promise in the recent breakthrough of the first DNA Schottky Diode. Other possible advantages are devices that are more compact, robust, environmentally friendly, require less power; and are amenable to flexible, just-in-time manufacturing; and has the potential to leverage the well established techniques such as combinatorical chemistry and high throughput nucleic acid sequencing. Results from this effort have the potential to: improve the performance of electronic devices, create new computational constructs, and define unique biotic-abiotic interfaces.

(U) Program Accomplishments and Plans:

FY 2007 Accomplishments:

- Developed process for room temperature fabrication of electronic materials with improved efficiency.
- Demonstrated 10x improvement in optical properties for high density storage with protein expression.
- Explored the integration of biological materials with several types of optical and electronic media and devices.
- Characterized the electrical properties of DNA Shottky Barrier Devices.

FY 2008 Plans:

- Develop computational models for designing novel biological materials for electronic media and devices.
- Develop computational models of DNA Shottky Barrier Devices to model the electron interaction at the DNA/metal interface, as well as the movement of the band gap barrier height.
- Develop new materials for device fabrication taking the computational models into account.

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– Demonstrate electronic devices fabricated with novel biological materials. These devices will have improved performance (e.g. current leakage, switching times) over standard electrical devices.

	FY 2007	FY 2008	FY 2009
Chip-to-Chip Optical Interconnects	3.355	2.000	1.000

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

(U) Program Plans

FY 2007 Accomplishments:

– Developed 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.
– Demonstrated high-speed (faster then 10 billions of bits per second (GBps)), low-power (less then 50 mW) optical transmitters/receivers.

FY 2008 Plans:

– Integrate optical transmitters/receivers and optical data paths with electronic packaging.

FY 2009 Plans:

– Complete integration activities and manufacturing approaches.

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	FY 2007	FY 2008	FY 2009
Photonic Analog Signal Processing Engines with Reconfigurability (PhASER)	0.000	9.000	7.891

(U) The goal of the Photonic Analog Signal Processing Engines with Reconfigurability (PhASER) program is the creation of new Photonic Integrated Circuit (PIC) elements, and associated programmable filter array concepts that will enable high-throughput, low-power signal processors. The focus is on the development of novel "Unit Cells," which may be used as building blocks to synthesize arbitrarily complex filters within a PIC platform for ultra-high bandwidth signal processing applications.

(U) Program Plans:

FY 2008 Plans:

- Define and design a novel analog photonic "Unit Cell," which is nominally comprised of a sub-array of waveguide-connected programmable active elements. The Unit Cell should be externally linkable with integrated waveguides, which will allow it to function as a building block in programmable PIC arrays for generalized high-order finite impulse response/infinite impulse response (FIR/IIR) filters.

FY 2009 Plans:

- Demonstrate an experimental Unit Cell concept.
- Determine how the Unit Cell, when arrayed within a high-density PIC, will perform.
- Develop a filter synthesis tool to demonstrate how Unit Cells will enable generalized high-order filters.
- Determine how unit cells will be programmed and tested at the chip-level to ensure high yield.

	FY 2007	FY 2008	FY 2009
Linear Photonic RF Front End Technology (PHOR-FRONT)	7.266	4.594	6.385

(U) The goal of the Linear Photonic RF Front End Technology (PHOR-FRONT) program is to develop photonic transmitter modules that can adapt their frequency response and dynamic range characteristics to mate with the full spectrum of narrow-band and broadband microwave

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transmission applications covering the 2 megahertz (MHz) – 20 gigahertz range. These field programmable, real-time adaptive photonic interface modules will find application in high dynamic range communications, radar and Electronic Warfare antenna applications.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated photonic demodulation and optical down conversion; >56 decibels (dBs) spurious free dynamic range (SFDR) measured over a 333 MHz instantaneous bandwidth for an radio frequency (RF)-to-intermediate frequency (IF) link.
- Demonstrated phase demodulator with all-optical phase-locked loop with SFDR of more than 124 dB- hertz (Hz) 2/3 with 3 megampere of photocurrent.
- Demonstrated < 10 Hz Full Width Half-Maximum laser line-width with locked “slow light” fiber laser.
- Compounded doping of glass for laser outputs of more than 500 megawatts.

FY 2008 Plans:

- Develop narrow line-width, 1,550 nanometer (nm) lasers with improved efficiency, relative intensity noise (RIN), and stability.
- Develop compact linear photonic receivers with improved sensitivity and dynamic range.

FY 2009 Plans:

- Develop and enhance narrow line width, 1,550 nm lasers with world record efficiency, RIN, and stability in a compact package.
- Develop and enhance compact and packaged linear photonic receivers with world record sensitivity and dynamic range.

	FY 2007	FY 2008	FY 2009
Optical Arbitrary Waveform Generation (OAWG)	15.636	6.964	4.284

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

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated 100 gigahertz (GHz) positive linear chirp with <5% least-squared deviation from mathematical ideal waveform.
- Demonstrated production of single-cycle, 1.5 GHz square wave with fidelity of <5% least-squared deviation from mathematical ideal waveform.

FY 2008 Plans:

- Develop 10 GHz octave-spanning carrier-envelope stabilized laser with integrated molecular frequency standard.
- Design and build miniature 10 gigabyte/s multi-channel, parallel bit-error rate testbed for integrated system testing.

FY 2009 Plans:

- Demonstrate 1,000 GHz positive linear chirp with <5% least-squared deviation from mathematical ideal waveform.
- Demonstrate production of single-cycle, 3 GHz square wave with fidelity of <1% least-squared deviation from mathematical ideal waveform.

	FY 2007	FY 2008	FY 2009
Transparent Displays	0.000	0.000	3.000

(U) The Transparent Displays program will develop technologies for the next generation of displays by leveraging the successes of previous programs in molecular electronics, as well as exploiting the optical plasmon phenomenology characteristics of nanoscale structures. Harnessing these tools will enable display systems that are transparent, low-power, light-weight, and high-speed. The new displays will replace existing displays in a host of applications, such as canopy-, windshield-, and window-integrated displays, and new light-weight avionics displays. Furthermore, the technology will enable innovative approaches to information sharing, such as integrated helmet display visors, bringing the digital battle space to the individual warfighter.

(U) Program Plans:

FY 2009 Plans:

- Develop new materials for thin, transparent, displays with daylight bright intensity using laser illumination.

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– Explore the use of new diffractive optics technology to provide lightweight optics with a comfortably viewable "virtual" image ahead of the viewer.

	FY 2007	FY 2008	FY 2009
Systems of Neuromorphic Adaptive Plastic Scalable Electronics (SyNAPSE)	0.000	0.000	3.000

(U) The Systems of Neuromorphic Adaptive Plastic Scalable Electronics (SyNAPSE) program will develop a brain inspired electronic "chip" that mimics the function, capacity, size, and power consumption of a biological cortex. If successful, the program will provide the foundations for functional machines to supplement humans in many of the most demanding situations faced by warfighters today. In particular, the objective of the program is to process video images for information abstraction (e.g. annotation) and task initiation. The two main technical challenges to achieving this vision are developing an artificial electronic synapse and developing a neural algorithm-architecture that exploits these synapses.

(U) Program Plans:

FY 2009 Plans:

– Develop hybrid CMOS and high-density synaptic crossbar arrays with density and function comparable to biological systems.
– Simulate large-scale neurally inspired systems using electronic device models.
– Develop standard testing protocols for assessing the performance of large neuromorphic electronic systems.

	FY 2007	FY 2008	FY 2009
Technology for Agile Coherent Optical Transmission & Signal Processing (TACOTA)	1.845	3.700	1.000

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

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(U) Program Plans:

FY 2007 Accomplishments:

- Developed signal design and compensation methods for nonlinear transmission impairments that occur in optical fibers.
- Developed indoor and outdoor testbeds to quantify advantages of mid-wavelength infrared versus short-wavelength infrared coherent optical communications.
- Successfully modeled the Optical Parametric Oscillator Wavelength Translation Approach.
- Demonstrated silica photonic crystal fiber based coherent wavelength translation between near-infrared and visible bands.

FY 2008 Plans:

- Demonstrate multi-spectral coherent optical transmission and frequency (wavelength) translation with high conversion efficiency and narrow line-width.
- FY 2009 Plans:
- Complete final program demonstrations.

	FY 2007	FY 2008	FY 2009
Ultrabeam	2.626	2.188	3.419

(U) The Ultrabeam program involved 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:

FY 2007 Accomplishments:

- Achieved peak X-ray output pulses estimated to exceed the predicted critical power requirement for channel formation experiments.

FY 2008 Plans:

- Demonstrated X-ray pulse spatial compression and observed preliminary indications of channel formation in a solid target.

FY 2009 Plans:

- Create a Gamma Ray Laser between 100 KeV and 1 MeV.

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	FY 2007	FY 2008	FY 2009
Photonic Bandwidth Compression for Instantaneous Wideband A/D Conversion*	0.000	3.235	4.445

*Formerly titled Ultra-Wideband A/D Conversion (UWB-ADC).

(U) The objective of the Photonic Bandwidth Compression for Instantaneous Wideband A/D Conversion program is to develop revolutionary technologies to enable Analog to Digital Converters (ADCs) with high-resolution and large instantaneous bandwidth while maintaining power consumption that is commensurate with user community requirements. It is expected that such ADCs would have a dramatic impact on signals intelligence capabilities such as direct down conversion of ultra high frequency through X-band radio frequency (RF) signals. Furthermore, ADCs enabled by this program alleviate the current ADC bottleneck in high capacity digital RF communications links by enabling more spectrally efficient wideband waveforms. This program aims to develop a bandwidth-compressing photonic front end that provides a force multiplier for any available back-end electronic ADCs.

(U) Program Plans:

FY 2008 Plans:

- Demonstrate transient ADC with 6.5 estimated number of bits (ENOB) signal-to-noise ratio over a 10 gigahertz bandwidth.
- Develop a low-power ADC with high-dynamic range for an improved ENOB.

FY 2009 Plans:

- Develop and enhance a low-power ADC with high-dynamic range for further improvement in the ENOB.

	FY 2007	FY 2008	FY 2009
Optical Antenna Based on Nanowires	0.000	2.000	1.000

(U) In optics, nanotechnology research will develop the ability to create structures of the same scale as incident light wavelengths. These structures can interact with and affect the incident light. This program will create nano-meter scale structures, which will act as optical antenna arrays that can respond coherently to electromagnetic fields at optical wavelengths. Each array element would be a nanostructure, such as a nanotube or nanowire, and provide a way to measure directly the field magnitude and phase in both space and time. A system based on this

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technology would potentially be smaller, lighter in weight, and able to move from the sub-optimal method of intensity-only measurements into the information-rich domain of complex imaging.

(U) Program Plans:
FY 2008 Plans:
– Study small element count two-dimensional array to identify performance and scaling relationships.
FY 2009 Plans:
– Characterize ability to measure the magnitude and phase of the incident light.

	FY 2007	FY 2008	FY 2009
3-D Microelectromagnetic RF Systems (3-D MERFS)	2.524	2.172	0.000

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

(U) Program Plans:
FY 2007 Accomplishments:
– Demonstrated >99.9% yield on 1-centimeter transmission lines on individual wafers, a 300x increase in yield.
– Demonstrated 11-layer fabrication process, enabling transmission line cross-overs, low-loss transmission lines, and high-Q (energy ratio) resonators.

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- Demonstrated monolithically fabricated 16-beam (4 simultaneous) transmit/receive aperture.
- Established transition path for Sat-Com-on-the-Move application through Communications-Electronics Research, Development and Engineering Center (CERDEC) to PM/Warfighter Information Network Terrestrial (PM/Win-T).
- Established Phase IIB yield improvement plan to improve total yield for 1,000 element manifolds from 5% to the 50% needed for Sat-com-on-the-move application.

FY 2008 Plans:

- Demonstrate 50% total yield for 1,000 element manifolds.
- Demonstrate resistor and active element integration.
- Demonstrate ability to stack and tile MERFS substrates.

	FY 2007	FY 2008	FY 2009
Chip Scale Atomic Clock (CSAC)	5.000	4.519	4.471

(U) The Chip Scale Atomic Clock (CSAC) 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 Global Positioning System (GPS) signal locking.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated feasibility and theoretical limits of miniaturization of cesium clock.

FY 2008 Plans:

- Demonstrate subcomponent fabrication including atomic chamber, excitation and detection function.

FY 2009 Plans:

- Demonstrate design and fabrication innovation for atomic-confinement cell and for gigahertz (GHz) resonators suitable for phase locking or direct coupling with atomic confinement cell.

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	FY 2007	FY 2008	FY 2009
Radio Isotope Micro-Power Sources (RIMS)	2.969	1.946	2.490

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

(U) Program Plans:

FY 2007 Accomplishments:

- Developed and demonstrated core technology for the direct capture of beta particles.
- Demonstrated longevity for the chosen radioisotope-to-electrical power conversion technique.

FY 2008 Plans:

- Demonstrate advances in power output and particle capture with high conversion efficiencies, while operating within safety considerations and limitations.
- Demonstrate advanced dielectrics with high stability suitable for solid-state capture devices.

FY 2009 Plans:

- Develop large-scale radioisotope generation cell based on beta particle capture.
- Demonstrate actual, long-lasting power generation in a militarily useful form factor.

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	FY 2007	FY 2008	FY 2009
Micro Isotope Micro-Power Sources (MIPS)	8.033	2.201	0.000

(U) The goal of the Micro Isotope Micro-Power Sources (MIPS) program is to demonstrate safe, affordable micro isotope power sources able to outperform conventional batteries in terms of energy and/or power density, and provide long lasting milliwatt-level power for an array of critical military applications, such as unattended sensors, perimeter defense, detection of weapons of mass destruction; and environmental protection.

(U) Program Plans:

FY 2007 Accomplishments:

- Fabricated boron carbide (BC) junctions with >10% conversion efficiency.
- Conducted survey of potential isotopes and determined isotopes most applicable to MIPS applications.

FY 2008 Plans:

- Demonstrate radiation hardened BC junctions with >10% efficiency.
- Demonstrate thermophotovoltiac conversion system.
- Demonstrate thermo electric conversion system.

	FY 2007	FY 2008	FY 2009
Design Tools for 3-Dimensional Electronic Circuit Integration	4.589	7.474	1.000

(U) The Design Tools for 3-Dimensional Electronic Circuit Integration program will develop a new generation of Computer Aided Design (CAD) tools to enable the design of integrated 3-dimensional (3-D) 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/radio

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frequency) systems and Systems-on-a-Chip for high performance sensing, communications, and processing systems for future military requirements.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated two-tier wafer-to-wafer bonding in both silicon-on-insulator and bulk complementary metal-oxide semiconductor (CMOS) technologies dense interlayer and thru-silicon via process.
- Improved commercial off-the-shelf (COTS) chip-to-chip stacking process developed and tested in two-tier field-programmable gate array (FPGA) stacks twelve-tier chip-to-chip stack demonstrated without electrical interconnects.
- Low temperature silicon, silicon germanium and germanium epitaxial growth processes developed to enable monolithic 3-D integration.
- 3-D architecture studies were performed assessing the advantages of 3-D topologies for enhancing digital performance.
- 3-D design kits, layout visualization and computer-aided design (CAD) tools were developed to enable 3-D design process.

FY 2008 Plans:

- Complete 3-D process technology development.
- Choose several compelling applications to map into the 3-D technologies developed.
- Begin fabrication of 3-D demo design chips.
- Complete fabrication of 3-D demo design chips.

FY 2009 Plans:

- Assess performance gains due to 3-D topologies.

	FY 2007	FY 2008	FY 2009
Multiple Optical Non-Redundant Aperture Generalized Sensors (MONTAGE)	2.248	0.000	0.000

(U) The Multiple Optical Non-Redundant Aperture Generalized Sensors (MONTAGE) program explored 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 were obtained

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through rational co-design and joint optimization of the imaging optics, the photo sensor array and the post-processing algorithms. By reaching well beyond conventional designs, MONTAGE sensors will realize optimal distribution of information handling functions between analog optics and digital post-detection processing.

(U) Program Plans:
FY 2007 Plans:
- Developed novel optical designs allowing depth reduction by 10x.
- Demonstrated ability to allocate highest spatial resolution to specified regions of interest in the image while maintaining medium resolution elsewhere.
- Demonstrated 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, and mechanical properties.

	FY 2007	FY 2008	FY 2009
Polymorphous Computing Architecture (PCA)	5.802	0.000	0.000

(U) The Polymorphous Computing Architectures (PCA) program developed a revolutionary approach to the implementation of embedded computing systems to support reactive multi-mission, multi-sensor, and in-flight retargetable missions. This revolutionary approach reduced the payload adaptation, optimization and verification processes from years to minutes. The program breaks the current development approach of hardware first and software last by moving beyond conventional silicon to flexible polymorphous computing systems. PCA architectures will adapt to efficiently perform a broad range of high-performance, challenging DoD processing functions utilizing a single architectural implementation.

(U) Two promising PCA architectures, eXtended Tera-op Reliable Intelligently Adaptive Processing System (XTRIPS) and eXtended MOrphable Networked microARCHitecture (XMONARCH), have bridged the gap between the prototypes developed in the PCA program and the transition-ready solutions that can be adopted by DoD and intelligence agencies. This effort included performing product-level and prototype development of processor chips and software development environments planned for future deployment by DoD and intelligence end users.

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(U) Program Plans:

FY 2007 Accomplishments:

- Successfully fabricated and delivered full implementation of the xMONARCH chip – first polymorphic computer – exceeding original goals.
- Successfully fabricated prototype TRIPS chip – first novel Explicit Data Graph Execution architecture computing chip - and supporting TRIPS compiler for implementing backend optimizations.
- Performed early small scale proof-of-concept testing, integration and evaluation of early polymorphic computing architecture prototypes – evaluation boards developed for both MONARCH and TRIPS devices.

	FY 2007	FY 2008	FY 2009
Vertically Interconnected Sensor Arrays (VISA)	5.200	0.000	0.000

(U) The Vertically Interconnected Sensor Arrays (VISA) program developed and demonstrated vertically interconnected, focal plane array read-out technology capable of more than 20-bits of dynamic range – over an order of magnitude higher than current state-of-the-art – enabling significant advances in the functionality of infrared systems. Vertical interconnections between the detectors and the read-outs that avoid first going through row-column multiplexers will allow for high frame rates concurrent with high resolution images.

(U) The VISA program expanded architectures for three-dimensional focal plane arrays, where multiple levels of signal processing were integrated into each pixel in the array, to include multiple processing layers, higher density vias (small openings in an insulating oxide layer that enable electrical connections, e.g., between layers) at the pixel, and coverage of a broad spectral band from the visible to the infrared. This increased on-chip processing power enabled new capabilities for smart sensors, such as high-speed imaging, on-chip threat discrimination, and anti-jamming. Defense applications include mid/long wavelength target acquisition systems for air and ground; smart missile seekers; anti-jamming; and imaging through high intensity sources. This program transitioned to PE 0603739E, Project MT-15.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed 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.

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- Demonstrated 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.
- Determined the best bands for improving the detection of objects in varying degrees of fog.

	FY 2007	FY 2008	FY 2009
Novel Techologies for Optoelectronics Materials Manufacturing (NTOMM)	0.000	3.750	3.000

(U) The goal of the Novel Technologies for Optoelectronics Materials Manufacturing (NTOMM) program is to develop and demonstrate new technologies for Group II-VI (e.g., Cadmium Selenide (CdSe)) and III-V (e.g., Gallium Nitride (GaN)) materials and device manufacturing, enabling imaging and emissive device fabrication at 1% to 10% current costs. This advance will dramatically expand the application space of such devices, by providing lower cost per large area infrared (IR) imaging systems, non-planar devices and systems, and thin film and flexible devices and systems. This program will demonstrate IR detectors and imagers, Light Emitting Diodes (LED), and solid-state lasers fabricated via new methods, and include a rapid demonstration of at least five times reduction in yielded device cost. The NTOMM program will leverage recent and ongoing developments in nano-material synthesis and assembly, which have demonstrated the potential for over 50% precursor stream usage in the fabrication of II-VI and III-V materials. An additional focus of the NTOMM program is the development of technologies to support the fabrication of low-cost high pixel density power efficient direct emission microdisplays. Current microdisplay systems use light modulation systems (Liquid Crystal Displays, Digital Micromirror Devices) and consequently only transmit a small fraction of the light from the illumination source thus limiting efficiency and use.

(U) Program Plans:

FY 2008 Plans:

- Develop synthesis methods that improve quality and monodispersity (characterized by particles of uniform size in a dispersed space) of Indium nitride (InN) and Indium gallium nitride (InGaN) nanocrystals.
- Develop cost effective synthesis methods for Group II-VI and III-V materials.
- Utilize controlled arrays of InGaN to form high efficiency Light Emitting Diode (LED) structures and imaging sensors in infrared.
- Assemble layer-by-layer heterostructures (characterized by dissimilar materials with non-equal bandgaps) from ordered planar arrays of nanocrystals.

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– Develop and demonstrate techniques for layer doping of heterostructure materials.
– Evaluate and select approaches for the development of affordable emissive microdisplays.

FY 2009 Plans:

– Demonstrate initial device concepts.
– Select fabrication technologies with 5x cost reduction potential.
– Demonstrate fabrication technologies that support the fabrication of affordable emissive microdisplays.

	FY 2007	FY 2008	FY 2009
Structured ASIC Design (StASD)	0.000	3.500	5.500

(U) Currently Application Specific Integrated Circuits (ASIC) have a 20-30x performance advantage over general-purpose programmable processors, this performance advantage is critical for high performance systems and platforms. Current ASIC design solutions are high in cost, require extensive time to design, apply to a single application, and need dedicated hardware; making them unattainable for most critical DoD systems. Also, when customizing ASICs for multiple applications, the overhead costs greatly increase resulting in reduced performance density, reduced clock speeds, and higher power. The development of a Structured ASIC Design (StASD) capability will provide the performance advantages of a customized ASIC but without the high overhead costs of programmable or fine-grain reprogrammable devices. The result will be highly novel, customizable ASICs that will dramatically enhance DoD application processing capabilities in terms of cost, time to design, and performance.

(U) Program Plans:

FY 2008 Plans:

– Complete studies establishing the potential impact and underlying principles of structured ASIC approaches and perform the initial analysis of selected potential approaches.

FY 2009 Plans:

– Determine which common high performance functional elements provide the best option for high performance functionality and the appropriate level and capability of interconnects for optimal customization.
– Investigate and evaluate potential architectures and implementations for structured ASIC.

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	FY 2007	FY 2008	FY 2009
Cognitively Augumented Design for Quantum Technology (CAD-QT)	2.000	4.000	5.000

(U) The Cognitively Augmented Design for Quantum Technology (CAD-QT) program has developed learning-based optimization tools and represents a stepping stone towards an intelligent search engine capable of guiding the designer through the complex trade spaces of quantum device design.

(U) Program Plans:

FY 2007 Accomplishments:

- Validated CAD-QT system by employing it to design optoelectronic modulator devices performing significantly beyond the current state-of-the-art.
- Investigated the exploitation of new fields of nanophotonics and plasmonics in which metal nanostructures converted electromagnetic radiation into charge density waves.

FY2008 Plans:

- Demonstrate the next generation CAD-QT tool to include thermoelectric coolers which employ superlattices to discriminate electrons and photons.

FY 2009 Plans:

- Determine methods of controlling the ultimate CAD-QT product.
- Apply diffusion graph data organization/dimensionality reduction to biological data.

	FY 2007	FY 2008	FY 2009
Non-Linear Math for Mixed Signal Microsystems	4.563	1.339	0.000

(U) The principal goal of the Non-Linear Math for Mixed Signal Microsystems program is to demonstrate a significant linearity enhancement capability based upon a digital signal processing approach, implemented in a high performance, very large scale integration (VLSI) chip that will enable wideband high-dynamic range sensor systems to be developed in a cost effective manner.

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(U) Program Plans:

FY 2007 Accomplishments:

- Developed 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.
- Explored 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.

FY 2008 Plans:

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

	FY 2007	FY 2008	FY 2009
THz Transistors (TT)	0.000	0.000	3.000

(U) The THz Transistors (TT) program will develop the technologies for terahertz (THz) transistors by following recently-established scaling laws for indium phosphide (InP) heterojunction bipolar transistors (HBTs). This program will focus on developing transistors larger than 1THz. In addition, the target integration level will be ~1000 transistors, sufficient for the circuit building blocks. Demonstration circuits will be >400 gigahertz (GHz) frequency dividers, >700 GHz power amplifiers, and a more complex mixed signal circuit at the end of the program. This program will address these super-scaled InP transistor challenges with innovative band gap engineering at the base and collector regions, aggressive reduction of the contact resistances and junction capacitances, reliable patterning processes for sub-100 nanometer emitter, and development of a multi-level dense interconnect process. Pushing into unchartered frequency domains, the testing, calibration, and modeling of THz transistors and circuits will also be addressed in this program.

(U) Program Plans:

FY 2009 Plans:

- Scale the state-of-art transistors to record operating speed and develop associated device models.
- Develop an integration process and fabricate simple demonstration circuits.

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– Develop a high yield fabrication process for complex demonstration circuits.

	FY 2007	FY 2008	FY 2009
Ultra Fast Lasers With Response > 100 GHz	0.000	0.000	2.000

(U) The objective of the Ultra Fast Lasers with Response > 100 GHz program is to develop ultra-fast lasers with modulation response > 100 gigahertz (GHz) resonance frequency. The frequency response of directly modulated semiconductor lasers has been limited by the relaxation oscillation to ~ 40 GHz. This fundamental limit can be overcome by strong optical injection locking as demonstrated recently in vertical cavity surface-emitting lasers (VCSEL) and edge-emitting distributed feedback (DFB) lasers with enhanced resonance frequencies of 50 and 72 GHz, respectively. These are the highest ever reported for such lasers. Despite the impressive experimental demonstrations, the fundamental limit of such frequency enhancement was not well understood until very recently. A newly derived analytical expression for the maximum enhanced resonance frequency shows that it is proportional to the square root of the external injection ratio, and inversely proportional to the photon lifetime of the slave laser cavity. This new understanding makes it possible to engineer the resonance frequency and to design monolithically integrated laser structures with a tailored radio frequency (RF) response. This concept will lead to more efficient, higher power, millimeter-wave optoelectronic sources with the resonance frequency scaleable to ~ terahertz (THz).

(U) Program Plans:

FY 2009 Plans:

– Investigate response of DFB and VCSEL.
– Explore “all-optical” mode-locking by matching the resonance frequency with the cavity round-trip frequency of the slave laser.
– Design monolithically integrated devices with the engineered RF response.

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	FY 2007	FY 2008	FY 2009
DESTINY	0.000	0.000	3.000

(U) The goal of Design-space Exploration and Synthesis Technology for Integrating Nontraditional Microsystems at Yield (DESTINY) program is to introduce a rational methodology for co-design of mixed signal systems with embedded fine-grain re-configurability and compensation. Beyond enabling the optimal application of compensation for high yield and adaptability in mixed signal function, such a design discipline would also lead to very new systems, which will dramatically change the accepted notions among customary component subsystems, buffer amplifiers, mixers, and digitizers. For instance, traditional hard tradeoffs between noise figure and linearity in front end amplifiers can be broken by deliberately designing nonlinearities, which ease the design of low noise figures without impairing system function through use of Non-Linear Equalizer (NLEQ) for overall improved system performance. The program will combine advanced ideas from robust optimization mixed signal architecture and design expertise from DoD and commercial companies, nonlinear signal processing expertise.

(U) Program Plans:
FY 2009 Plans:
- Establish methodologies to manage complexity in design trades through recent advances in fast, low-rank updates in physical models and distributed optimization.

	FY 2007	FY 2008	FY 2009
Ideal Channel Electronics (ICE)	0.000	0.000	2.400

(U) The objective of the Ideal Channel Electronics (ICE) program will be to develop the ideal channel field effect transistor (FET), with a composite channel integrating highly mismatched semiconductors in order to achieve unprecedented performance levels. The ICE FETs will enable ultra-high-speed high-power amplifiers, which are critical for high-performance wideband transmitters. One example of ICE will be to integrate an ultra-high mobility channel with a high-breakdown sub-channel for an ultra-fast high-power FET that does not exist today. Successful integration of different semiconductors to form a FET channel will demand no or little degradation in charge distribution and transport properties, i.e. maintaining high mobility and charge concentrations in the channels as well as introducing minimal and tolerable defects. The approach will

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be to develop methods for composite channel integration, such as wafer fusing the high mobility channel to the high breakdown channel or selective epitaxial regrowth. Significant technical challenges to be addressed include minimizing defects, which will affect the channel properties, alignment and bonding; methods to achieve mechanical integrity of dissimilar materials; and the achievement of high fabrication yields.

(U) Program Plans:
FY 2009 Plans:
- Develop mechanical integrity of dissimilar materials.
- Develop high fabrication yields.

	FY 2007	FY 2008	FY 2009
Ultra-Low Power Subthreshold Electronics (UPSE)	0.000	0.000	3.000

(U) The Ultra-Low Power Subthreshold Electronics (UPSE) program will achieve a >10x reduction in energy consumption for integrated circuits by developing technology that allows for circuit operation at the physical limits of power supply voltages. The objective of the UPSE program is to develop a circuit technology that will allow operation of devices in the subthreshold regime ($\leq$ 0.3 V) in contrast to the typical super-threshold regime ($\approx$ 1.0V). Particular emphasis is placed on the use of standard commercial complementary metal-oxide-semiconductor (CMOS) technology avoiding the need for specialized custom device fabrication. Application-specific parallelism will be leveraged for maintaining adequate performance in the sub-threshold regime while still consuming minimal power. A demonstration sensor or communication integrated circuit (IC) of significant military interest showing compelling low power performance and new mission capabilities will be built.

(U) Program Plans:
FY 2009 Plans:
- Develop subthreshold standard cell library for application specific integrated circuit (ASIC) designs in a state-of-the-art commercial CMOS foundry process.
- Identify candidate IC designs of DoD interest that could demonstrate ultra-low power sub-threshold performance.

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	FY 2007	FY 2008	FY 2009
Precision Opto-Mechanics - Mechanical Properties of Light	0.000	0.000	3.000

(U) The Precision Opto-Mechanics - Mechanical Properties of Light program will develop new optomechanical devices that utilize enhanced optical gradient forces within resonant nano-optical cavities for all-optical actuation and sensing. Specific target applications will include optically controlled nano-mechanical resonators and optically tunable filters. One area of application is the use of optical force to drive the coupling of guided modes across a small gap between a waveguide and the coupled resonator. This will lead to optical tuning of nano-mechanical resonators with a resonance frequency exceeding 1 gigahertz (GHz). Radio frequency (RF) filters and reference oscillators based on on-chip resonators offer a solution to the increasing count of RF components needed in miniaturized wireless systems.

(U) Program Plans:
FY 2009 Plans:
- Demonstrate all-optical tuning of a nano-mechanical resonator with a resonance frequency greater than 1 GHz.
- Demonstrate dynamic storage and release of optical pulses (10-100 per second) within the coupled double-layer resonator.
- Determine the bandwidth and sensitivity limits of optically driven resonators.

	FY 2007	FY 2008	FY 2009
Raman Beam Combining and Cleanup	0.000	0.000	3.000

(U) The objective of the Raman Beam Combining and Cleanup program is to develop a fundamentally new beam combining technology for delivering high brightness, diffraction limited and tunable output beams in the Mid-Wave infrared (MWIR). The approach does not require phase locking or wavelength locking of input lasers, yet there is no compromise in power or beam quality. Outputs from an array of free running MWIR lasers (such as quantum cascade laser) are added together to form a diffraction limited output with no loss of intensity or beam quality arising from their random relative phases. In the proposed approach, a multimode silicon Raman laser will provide the seed for a silicon power amplifier that exploits Raman amplification along with the Talbot effect in a multimode waveguide. While the resulting pump mode may have high aberration, the laser output will have a clean diffraction limited mode profile with high on-axis intensity. As a ubiquitous beam combiner that is agnostic with

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respect to input laser technology, this technology enables scalable high brightness diffraction limited output and has enormous potential as an efficient, compact, and robust source for infrared countermeasures and low noise MWIR amplification for chemical biological weapon detection.

(U) Program Plans:
FY 2009 Plans:
- Convert low quality pump into a diffraction limited beam.
- Combine multiple pumps via self imaging in multimode waveguide.

	FY 2007	FY 2008	FY 2009
SWEEPER	0.000	0.000	4.000

(U) The objective of the Short-range Wide-field-of-regard Extremely-agile Electronically-steered Photonic Emitter and Receiver (SWEEPER) program is to develop chip-scale dense waveguide modular technology to achieve true embedded phase array control for beams of ~10W average power, < 0.1 degree instaneous field of view (IFOV), > 45 degree total field of view (TFOV), and frame rates of > 100 Hertz in packages that are "chip-scale." Such performance will represent a three order of magnitude increase in speed, while also achieving a greater than two order of magnitude reduction in size. Additionally, the integrated phase control will provide the unprecedented ability to rapidly change the number of simultaneous beams, beam profile, and power-per-beam, thus opening up whole new directions in operational capability. Key technical challenges will center the ability to achieve the needed facet density (facet pitch should be on the order of a wavelength or two), control the relative phase across all facets to ~ 9-bits, and efficient coupling and distribution of coherent light to facets from a master laser oscillator with an integrated waveguide structure. Related projects and studies have pointed to the significant system-level pay-offs of the new proposed technology.

(U) Program Plans:
FY 2009 Plans:
- Create a chip-scale optical beam forming and scanning technology.
- Combine architecture and technology to address integrated control of phased optical signals.

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	FY 2007	FY 2008	FY 2009
Analog-to-Information (A-to-I)	0.000	0.000	3.000

(U) The Analog-to-Information (A-to-I) program will develop and demonstrate the practical advantages of several specific suggestions for mechanization uncovered in the study phase, whose further development is likely to provide dramatic breakthroughs in digitization techniques and hardware. Success in this program will show the way to hardware and system advances enabling accurate extraction of useful information from broadband environments crowded with diverse signals and interference spread over a large dynamic range, as required to meet DoD's requirements for radio frequency (RF) applications of the present and the future. Additionally, by extracting signals of interest during the measurement phase, A-to-I based approaches reduce the bandwidth and resolution requirements of analog-to-digital converters, and simultaneously reduces the data glut that impacts downstream processing of digitized signals.

(U) Program Plans:
FY 2009 Plans:
- Systematically exploit practical hardware and software implementations of the most promising approaches from study phase: compressive sampling, variable projective unfolding, and nonlinear affine encoders.

	FY 2007	FY 2008	FY 2009
Frequency Domain Analog Optical Signal Processor	0.000	0.000	4.000

(U) The objective of the Frequency Domain Analog Optical Signal Processor program is to develop an analog signal processor, which is capable of processing the equivalent of one teraflop per watt in the frequency domain. This program will require the development of large photonic integrated circuit-based filter arrays and associated photonic components which are many times more complex than the current state of the art.

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(U) Program Plans:
FY 2009 Plans:
- Implement an analog vector-matrix-multiply operation by utilizing programmable, high-quality, micro-ring-resonator filters arranged in a matrix to multiply and add photonic signal inputs.
- Develop an integrated frequency domain analog optical signal processor to enable improved signal processing capabilities for improved radio frequency communication, laser radar, bio-sensing, and optical computing capabilities on platforms such as unmanned aerial vehicles.

	FY 2007	FY 2008	FY 2009
J-Band Advanced Digital Receiver (JADR)	0.000	0.000	2.400

(U) Exploiting the pioneering architectural breakthroughs of the Digital Receiver program will create the next generation of analog-to-digital converters in low-power (4W) silicon germanium (SiGe) chip/complementary metal-oxide-semiconductor (CMOS) decoder chip integrated into a compact flip chip package. J-Band Advanced Digital Receiver (JADR) extends its impact into the J-band (10 gigahertz (GHz) to 20 GHz) by aggressive integration into scalable SiGe technology.

(U) Program Plans:
FY 2009 Plans:
- Direct radio frequency sampling strategies for 1-20 GHz input range.
- Devise and optimize SiGe/CMOS Monolithic RF Noise Shaping Modulator.

	FY 2007	FY 2008	FY 2009
REceivers Power Optimized for Reconnaissance and Tagging (REPORT)	0.000	0.000	4.000

(U) The goal of the REceivers Power Optimized for Reconnaissance and Tagging (REPORT) program is to demonstrate a 2.45 gigahertz (GHz) wake-up receiver, which will only consume less than 250 microwatts of power (~100X reduction) and will need < 10 Pico watt of the radio

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frequency (RF) input power to wake up the circuit (> 10^6x reduction). Additionally, this receiver will contain all necessary functions, including low-noise RF amplification, demodulation, baseband processing, wake-up decision logic and power conversion functions. To achieve these challenging power goals and necessary functionalities, the program will focus on the following technical developments. First, short-gate-width enhancement-mode High Electronic Mobility Transistor technologies will be developed to achieve low-noise RF gain at extremely low DC power levels. In addition, multi-layer interconnect process will be developed to monolithically integrate high-Q (~100), very high resonant impedance load inductors, which are critical to provide RF gain for low-power amplifier stages. Furthermore, innovative complimentary metal-oxide-semiconductor circuit designs will be explored to smartly utilize and manage bias currents for reducing total power consumption while providing necessary logic and signal processing capabilities.

(U) Program Plans:
FY 2009 Plans:
- Achieve low-noise RF gain at extremely low DC power levels.
- Integrate very high resonant impedence load inductors to provide necessary RF gain for low-power amplifier stages.

	FY 2007	FY 2008	FY 2009
Computational Imaging (CI)	0.000	0.000	3.000

(U) The Computational Imaging (CI) program seeks to develop new imaging constructs that exploit the full information content (intensity, phase, and frequency) at the detection plan to perform real-time image processing in the analog domain. This imagery will be combined with advanced digital image processing algorithms to leverage the unique image plane information for more rapid image analysis and target identification.

(U) Program Plans:
FY 2009 Plans:
- Develop image processing algorithms.
- Initiate the development of new imaging devices.

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	FY 2007	FY 2008	FY 2009
Non-contact EEG Technologies (NET)	0.000	0.000	3.000

(U) The goal of the Non-contact EEG Technologies (NET) program is to develop a non-contact Electroencephalograph (EEG) system based on new electric field sensor designs. The sensors would have performance characteristics to measure the electric field due to brain activity (0.5-21 hertz (Hz) signal with 500 nV/Hz½ sensitivity) and be compact enough to mount on a light-weight cap or inside a warfighter's helmet. The signal from the individual sensors would then be collected and sent wirelessly to a unit mounted on the subject for further processing. The main challenges are to develop high sensitivity sensors in a small form factor, overcome one over frequency noise in sensing the electric fields and in multiplexing the sensor array to produce a high spatial resolution image of brain activity. In order to transition the EEG system to the brain monitoring community (both DoD and universities), the developed system's performance will be validated versus state-of-the-art wet electrode systems under a variety of operational situations.

(U) Program Plans:
FY 2009 Plans:
- Develop sensor technology to measure the electric field of brain activity.
- Demonstrate single non-contact sensor for EEG.

	FY 2007	FY 2008	FY 2009
Ultra Low Loss Photonic Integrated Circuits and Processors	0.000	0.000	3.000

(U) The Ultra Low Loss Photonic Integrated Circuits and Processors program will realize high time-bandwidth products in planar optical waveguide technologies, thereby enabling compact, low power, high dynamic range frequency processors for signals intelligence (SIGINT) and imagery intelligence (IMINT).

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(U) Program Plans:
FY 2009 Plans:
- Develop an on-chip, ultra low-loss waveguide technology.
- Develop and enhance an on-chip, ultra low-loss waveguide technology to meet desired "fiber-like" performance.

	FY 2007	FY 2008	FY 2009
Processing Algorithms with Co-design of Electronics (PACE)	0.000	0.000	3.000

(U) The Processing Algorithms with Co-design of Electronics (PACE) program enables the co-design of the next generation of embedded signal processing algorithms and architectures capable of processing large sparse matrix data structures associated with graph structured signal processing algorithms. Graph algorithms are the key to post-detection signal processing, helping to "connect the dots" in a huge variety of emerging challenges ranging from social network analysis, change detection in massive data transactions, and forensic and predictive analyses of activities from video data over wide areas and extended times. The goal of the PACE program is to provide the DoD with an architecture and algorithm co-design capability for what is likely to be the next big thing in DoD embedded signal processing: Graph-structured signal processing. Solutions available today that might meet these mission requirements are limited by prohibitively long and costly manual design times. The PACE program will provide signal processing capabilities not possible today while achieving dramatically reduced design time and cost.

(U) Program Plans:
FY 2009 Plans:
- Recast algorithms into sparse arrays.
- Co-design mapping to novel high performance computing architectures.

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	FY 2007	FY 2008	FY 2009
Visible InGan Injection Lasers (VIGIL)	0.000	2.000	5.382

(U) The objective of the Visible InGan Injection Lasers (VIGIL) program is to demonstrate injection lasers emitting in green, at l=500 nanometers (nm). Specific program goal is to demonstrate green injection lasers operating continuous wave at room temperature with the power output up to 1 watt (W), wallplug efficiency of 30%, and stable output during a time period longer than 1,000 hours. These lasers will be fabricated with a yield of 20%. VIGIL lasers will enable applications requiring a close match between the light source and the peak response wavelength of the human eye. Another class of applications will take advantage of the minimum absorption of sea water in the blue-green spectral region. Diverse other applications include miniaturized displays and pumps for generation of high-frequency mode-locked combs.

(U) Program Plans:

FY 2008 Plans:

- Scale the output power of the laser to at least 100 milliwatts (mW).
- Achieve wallplug efficiency of 20%, stable operation of 500 hrs.
- Demonstrate wafer yield of at least 10%.

FY 2009 Plans:

- Demonstrate room temperature 500 nanometer lasers and validate the technical approach for device demonstrations.
- Scale the output power of the laser to at least 100 mW, achieve wallplug efficiency of 20%, stable operation of 500 hours, and demonstrate wafer yield of a least 10%.

	FY 2007	FY 2008	FY 2009
Quantum Sensors	0.000	0.000	7.000

(U) The Quantum Sensors program is developing approaches to exploit non-classical effects called entanglement to improve the resolution and range of military sensors. Quantum sensors will retain the generally better propagation characteristics of long wavelength light while achieving the better spatial resolution of short wavelength radiation. Conventional classical sensors rely on light with shorter wavelengths, like blue light, to

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produce sharp images. As wavelengths increase, for example from blue to infrared, the classical resolution decreases. Quantum sensors will be able to retain high resolution as the wavelength increases using a non-classical effect called entanglement. Two broad classes of sensor are under consideration. Type I quantum sensors propagate entangled photons to a target and back to a detector, where quantum effects may enhance resolution. Type II quantum sensors propagate classical radiation to the target, and entangled photons are used within the detector to improve resolution. A third class of approach, based on ghost imaging, is also being explored. During the theoretical proof stage in FY 2007 to 2008 this program is funded under PE 0601101E, Project MS-01.

(U) Program Plans:
FY 2009 Plans:
- Commence component technology development.
- Begin Quantum Sensor systems analysis to quantify achievable system performance and component technology requirements.

	FY 2007	FY 2008	FY 2009
Parametric Optical Processes and Systems (POPS)	0.000	1.000	2.142

(U) The Parametric Optical Processes and Systems (POPS) program aims to direct terabits per second (Tb/s) optical switching to move ultra-short optical bits in time and wavelength to accomplish wavelength grooming. This program will develop disruptive manufacturing processes to reduce the cost and delivery time for future DoD systems.

(U) Program Plans:
FY 2008 Plans:
- Develop basic building block components - multiple-pump amplifiers.

FY 2009 Plans:
- Initiate quantitative system demonstrations in wavelength grooming.
- Develop technology in highly nonlinear dispersion flattened fiber.

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	FY 2007	FY 2008	FY 2009
National Secure Foundry Initiative	2.000	0.000	0.000

(U) The Secure Advanced Fabrication Facility for Electronics (SAFFE) developed nanoelectronics innovations in support of homeland security and national defense applications with target products ranging from power electronics systems, advanced superconductors, integrated "nanochip" solutions for lithography, 3-Dimensional integration, device modeling and simulation, and metrology applications. Scaling down of semiconductor device feature sizes has led to advanced electronic components and new capabilities for signal and data processing.

(U) Program Plans:
FY 2007 Accomplishments:
– Pursued research concepts for shrinking semiconductor devices to the nanoscale and explored applications to integrated microsystems.

	FY 2007	FY 2008	FY 2009
Characterization, Reliability & Applications for 3-D Microdevices	2.600	0.000	0.000

(U) The Characterization, Reliability & Applications for 3-D Microdevices explored innovative processes to improve the fabrication of 3-Dimensional (3-D) Microdevices.

(U) Program Plans:
FY 2007 Accomplishments:
– Developed innovative processing instrumentation for the fabrication of 3-D Microdevices.

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3-D Technology for Advance Sensor Systems	2.200	2.400	0.000

(U) The 3-D Technology for Advance Sensor Systems effort will exploit 3-Dimensional (3-D) technology for applications in Advance Sensor Systems.

(U) Program Plans:
FY 2007 Accomplishments:
– Explored 3-D technology innovation for application to Advance Sensor Systems.
FY 2008 Plans:
– Apply 3-D technology to device implementation.

(U) **Program Change Summary:** *(In Millions)*	**FY 2007**	**FY 2008**	**FY 2009**
Previous President's Budget	239.370	213.529	219.844
Current Budget	215.742	196.707	211.457
Total Adjustments	-23.628	-16.822	-8.387
Congressional program reductions	-7.500	-19.222	
Congressional increases	0.000	2.400	
Reprogrammings	-10.000		

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SBIR/STTR transfer	-6.128

(U) Change Summary Explanation:

FY 2007	Decrease reflects the Section 8043 Recission, the DoDEA/DSS reprogramming, and the SBIR/STTR transfer.
FY 2008	Decrease reflects a PE execution adjustment and reductions for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions; offset by a congressional add for 3-D Technology for Advanced Sensor Systems.
FY 2009	Decrease reflects minor rephasing of electronics programs.

(U) Other Program Funding Summary Cost:

- Not Applicable.