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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, R-1 #17

COST (In Millions)	FY 2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009
Total Program Element (PE) Cost	340.446	434.426	465.544	461.043	457.485	481.035	470.154	474.052
Materials Processing Technology MPT-01	162.434	134.744	133.312	135.478	140.495	162.006	158.139	158.959
Microelectronic Device Technologies MPT-02	106.678	121.993	163.776	179.073	196.340	209.592	214.399	217.572
Cryogenic Electronics MPT-06	7.823	4.149	4.911	9.808	14.678	16.611	19.523	19.504
Beyond Silicon MPT-08	63.511	88.459	78.871	47.826	19.570	14.657	0.000	0.000
Biologically Based Materials and Devices MPT-09	0.000	85.081	84.674	88.858	86.402	78.169	78.093	78.017

(U) Mission Description:

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

(U) The major goal of the Materials Processing Technology project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of

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materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling for improvements in logistics (i.e., novel power sources, water purification, etc.).

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

(U) The Cryogenic Electronics project funds specific applications of thin-film electromagnetic materials in electronic devices and circuitry for military applications. Thin-film electromagnetic materials have reached a stage of development where specific applications can be identified in electronic devices and circuitry for military systems. Films may be deposited and patterned to form electromagnetic components in ways that are similar to, and compatible with, the processes of conventional semiconductor manufacturing. Such electromagnetic components, as well as complementary metal oxide semiconductors (CMOS), work best at lower temperatures, so that cryogenic packaging generally will be required for optimum performance. Thin-film high temperature superconducting (HTS) components packaged with cryogenic devices are being applied to radars, electronic warfare suites, and communications systems to enhance performance by more than an order of magnitude while reducing size and power requirements. Particular demonstrations include detection and geolocation of targets of high interest based upon low-level characteristic emissions and communications receivers with greater immunity to interference.

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

(U) The Biologically Based Materials and Devices Project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials and devices as well as the commensurate influence of materials, physics and chemistry on new approaches to

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biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials for enhancement of performance, the development of multifunctional transducers based on biological membranes, and the application of magnetic materials in biological applications.

(U) **Program Change Summary:** *(In Millions)*	**FY 2002**	**FY 2003**	**FY 2004**	**FY2005**
Previous President's Budget	344.554	440.500	550.126	594.165
Current President's Budget	340.446	434.426	465.544	461.043
Total Adjustments	-4.108	-6.074	-84.582	-133.122
Congressional program reductions	0.000	-19.874		
Congressional increases	0.000	13.800		
Reprogrammings	+0.506	0.000		
SBIR/STTR transfer	-4.614	0.000		

(U) Change Summary Explanation:

FY 2002	Decrease reflects SBIR transfer offset by below threshold reprogramming.
FY 2003	Decreases reflect Congressional program and undistributed reductions, offset by adds in the areas of optoelectronics, photonics, heat actuated coolers, strategic materials, 3D structures and friction stir welding.
FY 2004 - 2005	Decrease reflects reprioritization of Agency requirements.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Materials Processing Technology, MPT-01	162.434	134.744	133.312	135.478	140.495	162.006	158.139	158.959

(U) Mission Description:

(U) The major goal of this project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling for improvements in logistics.

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Structural Materials and Devices	32.500	33.000	35.073	42.344

(U) The Structural Materials and Devices program is exploiting emerging material science concepts and processing approaches to tailor the properties and performance of structural materials and devices to DoD requirements. Thrusts in this area include new concepts for lightweight personnel protection as well as ultra lightweight materials, amorphous and multi-functional materials for lowering the weight and increasing the performance of aircraft, ground vehicles, and spacecraft structures. Approaches are also being developed for reducing the risk of introducing new materials in defense acquisitions and maintaining them in the field. Techniques are being established for assessing damage evolution and predicting future performance of the structural materials in Defense platforms/systems through physics-based models and advanced interrogation tools. New, low cost processing and fabrication techniques are also being developed to enable expanded use of new materials and structures in Defense applications.

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(U) Program Plans:

- Develop and downselect promising concepts for ultra-lightweight armor with 100 percent improvement over current materials; transition promising concepts to Army vehicle armor programs.
- Develop multifunctional materials concepts designed to provide significant improvement in the capabilities of Defense systems by providing additional functions (e.g., self-healing, thermal control, blast protection, and power) to load bearing structures, quantify their performance and fabricate specific prototype systems.
- Demonstrate multifunctional structure plus battery for micro unmanned air vehicle wing that yields three times more duration than with traditional wing structures and conventional batteries.
- Develop and verify models that predict bulk amorphous metal formation and behavior; use these models to produce bulk amorphous materials with superior properties (including increased fracture toughness and high strain rate behavior) over crystalline material.
- Demonstrate fabrication (forming, joining, etc.) technologies that yield bulk amorphous metals suitable for Defense applications, especially those that require high fracture toughness, even at high strain rates, and quantify the impact of using bulk amorphous materials in construction of land vehicles and naval vessels.
- Demonstrate and validate solutions to critical technical issues for the accelerated insertion of materials that will allow designers to cut the insertion time of new materials by over 50 percent using materials of high value to DoD (turbine metals, aircraft structures).
- Apply the accelerated insertion methodology to new materials that, if inserted, will significantly improve Defense systems.
- Explore techniques for large volume, low cost synthesis and assembly of nanomaterials and nanotubes with controlled attributes; exploit assembly processes to develop hierarchical/topological arrangements and structures to attain unique and multiple properties.
- Develop models and mathematical techniques that, integrated with sensor data, capture the physics of failure and behavior prediction in materials suitable for assessing in-situ damage accumulation and providing current state awareness and structural performance prediction for Defense systems.
- Demonstrate the use of flight information to predict life and failure of critical structural components.
- Demonstrate novel, cost effective processing routes for structural materials of interest to Defense (e.g., Ti).
- Demonstrate novel and reproducible process routes for directed, localized and controlled microstructure modification to achieve substantial improvements in structural material properties of interest to Defense, including bronze castings for Navy applications.
- Explore concepts and demonstrate materials technologies for large, ultra-lightweight and controllable space structures.

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	FY 2002	FY 2003	FY 2004	FY 2005
Smart Materials and Actuators	29.992	31.000	39.739	35.000

(U) In this thrust, smart materials, sensors and actuators for the control of the aerodynamic and hydrodynamic behavior of military systems are being developed and demonstrated to increase performance and lower detectability of aircraft, helicopters, and submarines as well as to increase human performance. New piezoelectric materials are being developed that will dramatically increase the performance of Navy sonar/systems. "Intrinsically smart" materials that provide self-diagnosis and/or self-repair will be developed as well. Machines are being developed that would increase the individual soldier's physical capabilities by augmenting speed, strength, and endurance. Advanced materials, devices, and structural architectures are being investigated that would allow military platforms to morph or change shape, thus adapting optimally to mission requirements.

(U) Program Plans:

- Demonstrate pilot production technology for piezocrystals in quantities and at cost suitable for prototype devices.
- Demonstrate enhanced Naval sonar device/system performance using piezocrystals over a spectrum of representative applications on the laboratory scale, and for a selected few applications on the field scale.
- Develop exoskeleton architectures that are kinematically and dynamically compatible with human physiology.
- Design, demonstrate and validate an integrated, untethered, and self-powered exoskeleton system for augmenting the locomotion and strength of soldiers. The interface of the machine and human will be dramatically enhanced by the development of novel sensor architectures and control algorithms.
- Scale-up piezocrystal materials technology and, in concert with the Services, develop fieldable Defense systems (e.g., sonar) exploiting these revolutionary materials.
- Develop and demonstrate novel fluidic and mechanical devices, and their associated driving electronics, that exploit smart material transducers in order to create new high power actuators for a variety of military applications.
- Develop, design and test the actuators, materials, and control architectures necessary for achieving precise shape change in an airframe to demonstrate the advantages and enable capabilities afforded by the ability to change shape (morphing).
- Extend morphing concepts to Defense platforms beyond aircraft (e.g., spacecraft).

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	FY 2002	FY 2003	FY 2004	FY 2005
Functional Materials and Devices	44.233	28.344	18.500	18.134

(U) For the first time, this thrust area includes programs related to developing advanced functional materials from the former thrust area Mesoscopic Structures and Devices. New materials and concepts are applied to the development of functional materials and devices. This includes advanced magnetic materials for high sensitivity, magnetic field sensors; non-volatile, radiation hardened magnetic memories with very high density, short access time, infinite cycleability and low power; novel materials and device structures for high frequency acoustic imaging; and electroactive polymers for sensing, actuating, and analog processing. New permanent magnetic materials with significantly higher magnetic strength and higher operating temperature for motors, generators, flywheels, bearings and actuators are also being explored. Unique fabrics that can change their porosity or display information will be investigated. Engineered materials (metamaterials) are being developed that provide improvements in electromagnetic behavior across the complete array of defense applications. Technology for the mask-less, direct-write of mesoscopic integrated conformal electronics will enable the three-dimensional integration of both active and passive components, significantly reducing the size, weight and cost of integrated electronics functions (circuits, batteries, antennae, etc.).

(U) Program Plans:

- Demonstrate the use of conducting polymers for analog processing of image data 10 times faster than and using 10 times less power than digital approaches.
- Demonstrate the use of electroactive polymers in color displays.
- Demonstrate both 1Mbit standalone Magnetic Random Access Memory (MRAM) at high density and high speed and lower density rad hard embedded memory and transitioned to Navy Strategic Programs and DTRA.
- Demonstrate frequency and phase agile antennas, filters, phase shifters, and matching elements and transitioned to Army and Navy communication and remote sensing applications.
- Demonstrate the ability to direct write mesoscale (10 microns to 1 mm) electronic circuitry, conformally, on low temperature substrates (plastic, paper, etc.), using computer aided design/computer aided manufacturing (CAD/CAM) software.
- Demonstrate quantitative advantages of using the electronic capabilities (sensors, transistors, etc.) of electroactive polymers in Defense applications.
- Demonstrate the ability of an electroactive polymer to perform muscle-like sensing and actuation in Defense robotic applications.
- Develop and demonstrate novel magnetic meta-materials including: 1) high temperature, high strength soft magnetic materials for

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rotor and stator applications in turbine environments; and 2) permanent magnets with superior energy products (> 30 MGOe for isotropic systems and > 60 MGOe for anisotropic systems) for DoD motor applications.

- Develop and demonstrate novel microwave meta-materials (including artificial ferrites, nanocomposite ferroelectrics, artificial magnetodielectrics, and negative index materials) that will enable novel antenna and radar designs with reduced size and improved bandwidth and efficiency.
- Demonstrate the ability to conformally direct write large, flexible arrays of functional transistors, filters, and other active electronic components with < 10 micron resolution.
- Demonstrate microfabrication technology for non-silicon MEMS devices and fabricate structures for evaluation.
- Demonstrate feasibility of using functional (conducting, piezoelectric, etc.) fibers and novel textile techniques to create electronic textiles for military applications.

	FY 2002	FY 2003	FY 2004	FY 2005
Materials for Logistics (Air, Water, Power)	35.558	37.000	40.000	40.000

(U) The Materials for Logistics thrust combines the previous categories of Advanced Energy Technologies and those aspects of Mesoscopic Structures and Devices related to logistics technologies. This thrust will apply novel materials and structures to reduce the logistics burden of the warfighter in the field. New materials and concepts for increasing the availability of portable power to the soldier are being investigated, as are approaches for deriving power from the environment for soldiers and sensors. Novel approaches for direct energy conversion from thermal sources such as submarine nuclear reactors are also being examined. New materials and designs will also be applied to the development of novel mesoscale engines (e.g., Stirling, water-lubricated steam engines) that will provide needed power on the battlefield. Hybrid superconducting/cryogenic components will provide a new paradigm for power electronics for the “all electric” platforms of the future. Finally, materials technologies will also be employed in novel approaches for obtaining and purifying water in the field as well as air purification.

(U) Program Plans:

- Fully integrate and demonstrate energy harvesting technologies with military applications.
- Design, develop, and demonstrate portable power sources in the 20 Watt power range suitable for several mission scenarios including: 1) a 3 hour micro air vehicle reconnaissance mission (1000 Whrs/kg); 2) a 3 day land warrior mission (2000 Whrs/kg); and 3) a 10 day special operation forces mission (3000 Whrs/kg).

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- Develop and demonstrate enabling direct thermal to electric conversion technologies with potential for high (> 20%) conversion efficiencies and high (> 1 W/cm^2) power densities for DoD and commercial power generation applications.
- Demonstrate concepts for highly power-dense, man-portable kilowatt generators that will reduce the logistics burden for the soldier in the field.
- Demonstrate efficient, low cost, 200 watt Stirling engine for Defense applications, including powering of small, motorized vehicles.
- Develop and demonstrate unique, energy-saving concepts for obtaining water from non-traditional sources (water-from-air, combusted hydrocarbons, and urine) for the individual warfighter and small groups of soldiers.
- Develop and demonstrate novel technologies for low-power purification of any brackish or salty brine solution.
- Explore novel approaches for power generation based on sonoluminescence, Stimulated Isomer Energy Release (SIER) and other related technologies; transition SIER to project TT-04.
- Demonstrate a prototype hybrid superconducting/semiconducting power module for satellite (100 kW) or terrestrial (5 MW) application with high efficiency and reliability with significantly reduced size and weight.

	FY 2002	FY 2003	FY 2004	FY 2005
Bioinspired and Bioderived Materials and Devices	14.251	0.000	0.000	0.000

(U) This program will explore and exploit the unique characteristics of biologically inspired and biologically derived materials and devices through the understanding, control, and emulation of the structure and chemistry of the interface between man-made and biotic materials, and hybrid bioelectronics that electronically control biological organisms or use biological intelligence for smart materials. The direct utilization of biological systems for the production of unique, bioderived materials will be investigated. Structure and function emulated from biological systems will result in new biomimetic systems that capture unique locomotion and sensing schemes. The fundamental operating principles of biomolecular motors will be developed and exploited to design nano to macro scale devices having unparalleled energy efficiency. Bio-inspired optical components will allow the development of multifunctional optical systems with reduced complexity and weight. Biologically based materials efforts moved to project, MPT-09, in FY 2003, a project created in response to the growing and pervasive influence of biological science on the development of new materials and devices.

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	FY 2002	FY 2003	FY 2004	FY 2005
Advanced Materials, Frequency Tunable Materials	1.500	0.000	0.000	0.000

(U) Program Plans:
- Investigated nano particles for the fabrication of frequency tunable materials and components.

	FY 2002	FY 2003	FY 2004	FY 2005
Strategic Material Manufacturing	3.400	3.400	0.000	0.000

(U) Program Plans:
- Continue to develop new manufacturing approaches for cutting tools and other ceramics used for Defense applications.

	FY 2002	FY 2003	FY 2004	FY 2005
Detection and Destruction of CW-Nanotechnology	1.000	0.000	0.000	0.000

(U) Program Plans:
- Developed all-polymer microelectronic and optoelectronic systems for broad military applications including a polymeric tunneling sensor that combined MEMS technology with nanotechnology and an optical lens system using advanced micro and nano fabrication techniques.

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	FY 2002	FY 2003	FY 2004	FY 2005
Heat Actuated Coolers	0.000	1.000	0.000	0.000

(U) Program Plans:

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

	FY 2002	FY 2003	FY 2004	FY 2005
Friction Stir Welding	0.000	1.000	0.000	0.000

(U) Program Plans:

– Investigate the applicability using Friction Stir Welding to join amorphous alloys without recrystallization.

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

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Microelectronic Device Technologies, MPT-02	106.678	121.993	163.776	179.073	196.340	209.592	214.399	217.572

(U) Mission Description:

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

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Photonic Wavelength and Spatial Signal Processing (Photonic WASSP)	10.501	9.270	0.000	0.000

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

(U) Program Plans:
- Develop micro-machined optical elements for spectral bands 300 to 500 nm and 3 to 15 microns.
- Initiate integration of the passive elements into beam conditioners.
- Demonstrate integration with packaging module.

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- Demonstrate module in a testbed for bio-chemical sensing and spectral imaging.
- Transition technology to DoD hypospectral/imaging programs and systems.

	FY 2002	FY 2003	FY 2004	FY 2005
Adaptive Focal Plan Arrays (AFPA)	0.000	5.663	6.875	7.503

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

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

	FY 2002	FY 2003	FY 2004	FY 2005
Vertically Interconnected Sensor Arrays (VISA)	8.954	11.550	11.983	10.773

(U) The Vertically Interconnected Sensor Arrays (VISA) program will develop and demonstrate focal plane array (FPA) read-out technology capable of extremely high dynamic range sensitivity enabling significant advances to the functionality of infrared systems. This will be achieved by the development of novel vertical 3D integrated read-out circuits for sensor arrays designed with advanced high performance circuit

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architectures. A wide range of military imaging systems will be enabled, i.e., detection of targets appearing in low contrast, high clutter, or low light scenes and laser jamming avoidance.

(U) Program Plans:

- Develop a wafer stacking process incorporating high-density vias and design novel circuits that enable high frame rates, counter measure hardening and adaptive signal processing functions on a concept test chip.
- Demonstrate a high dynamic range A/D VISA technology based sensor designed with advanced high performance circuit architecture implemented in stacked semiconductor process with high-density interconnections.

	FY 2002	FY 2003	FY 2004	FY 2005
Imaging Coherent Optical Radar	0.000	0.000	5.000	7.000

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

(U) Program Plans:

- Demonstrate nanofabrication techniques for realizing broadband coherent optical sources with tailored spectral output for imaging, communication, targeting and countermeasure applications.

	FY 2002	FY 2003	FY 2004	FY 2005
Highly Integrated Millimeter Wave Electronically Scanned Array	0.000	0.000	3.000	5.000

(U) The Highly Integrated Millimeter Wave Electronically Scanned Array (ESA) program will investigate the possibility of making complete millimeter wave active arrays on a single or a very small number of wafers. The program will exploit new technologies being developed commercially that allow GaAs active components to be placed on Si wafers, and advances in InP and SiGe that may allow an entire MMW ESA to

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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.

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

	FY 2002	FY 2003	FY 2004	FY 2005
Analog Optical Signal Processing (AOSP)	7.334	12.008	14.733	14.808

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

(U) Program Plans:
- Perform analysis of analog signal characteristics of military RF systems.
- Create, model and simulate new photonic-based optical signal processing techniques of ultra-high bandwidth analog signals.
- Evaluate anticipated system performance improvements due to novel signal processing algorithms and determine the resulting photonic component performance requirements.
- Test and evaluate signal processing techniques of analog signals.
- Evaluate photonic component performance requirements.
- Design, fabricate and test individual photonic components capable of meeting RF signal processing requirements.

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

	FY 2002	FY 2003	FY 2004	FY 2005
Precision Optical Oscillators	0.000	0.000	3.929	4.904

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

(U) Program Plans:

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

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	FY 2002	FY 2003	FY 2004	FY 2005
Intelligent Digitization of Analog Sensor Information	0.000	0.000	6.000	9.000

(U) The overall goal of the Intelligent Digitization of Analog Sensor Information program is to significantly advance analog/digital conversion technology for insertion into a wide variety of military platforms. A specific goal is a ten fold improvement in the data conversion metric (bandwidth X resolution/power). A promising approach is to develop and implement new high performance architectures that overcome the limitations of current analog mixed signal circuits by harnessing the enormous calculational power of the most aggressive digital CMOS technology. This program will seek new, innovative approaches to A/D circuit design and transition the most promising architectures to the Defense industry for refinement and incorporation into Defense sensor systems. The resulting technology will impact many Defense communications, radar, and SIGINT systems.

(U) Program Plans:

- Identify application for adaptable mixed-signal processors, component requirements, and technical challenges.
- Identify concepts for adaptable mixed-signal processor functions including flexible interconnect networks, data flow sensors, optimization algorithms and data routers.
- Demonstrate concepts for chip-level flexible interconnects.
- Demonstrate algorithms and circuits for architecture optimizers.
- Complete design concepts for data flow sensors, resource allocation, and data-traffic routers.
- Demonstrate adaptability concepts in digital and mixed signal circuits.
- Demonstrate communication between adaptable mixed-signal and digital circuits.

	FY 2002	FY 2003	FY 2004	FY 2005
Chip Scale Atomic Clock	5.963	13.196	12.636	12.750

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

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

	FY 2002	FY 2003	FY 2004	FY 2005
Technology Efficient, Agile Mixed Signal Microsystem (TEAM)	7.390	12.348	16.863	16.712

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

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

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	FY 2002	FY 2003	FY 2004	FY 2005
Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST)	0.000	21.337	21.050	19.000

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

(U) Program Plans:

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

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	FY 2002	FY 2003	FY 2004	FY 2005
Clockless Logic	0.000	0.000	4.911	7.808

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

(U) Program Plans:

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

	FY 2002	FY 2003	FY 2004	FY 2005
Interfacing Nanoelectronics	0.000	0.000	6.000	8.000

(U) As IC technology progresses towards nano (less then 100nm) dimensions, the transistors and logic blocks are becoming smaller and faster than the interconnects. On-chip wiring is now a major limiter in logic delay, power dissipation and yield, a situation that will be seriously aggravated in nanoelectronic systems. Interconnects directly affect performance and power dissipation of digital processors, which are pervasive in DoD systems. Additional stringent demands on interconnects will be generated by "new frontier" nanowire or single-molecule-based devices scaled down to nanometer dimensions that are expected to be the backbone of future generation computing and communication systems. While performance is a critical limitation, existing interconnect solutions also introduce considerable noise into the system because of electromagnetic coupling between closely spaced lines. Such issues must be overcome to achieve future advanced sensor systems. This program will develop novel methods for advanced interconnect technology at all levels (board to chip) with primary emphasis on overcoming on-chip bottlenecks.

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(U) Program Plans:
- Develop alternatives to wired interconnects to include both optical and RF.
- Implement reduced interconnect length methods based on 3D interconnected systems, either by multiple layers of transistors or by 3D stacked chips in a single package.
- Apply communication network and signaling approaches to minimize electrical interconnect length in the design of complex signal processing chips.
- Develop new system-in-a-package concepts for heterogeneous systems (multiple functions and multiple materials integrated via interconnect) that includes advanced thermal management and self-contained power elements.
- Develop integrated modeling and simulation tools capable of thermoelectromechanical system design.

	FY 2002	FY 2003	FY 2004	FY 2005
Design Tools for 3-Dimensional Electronic Circuit Integration	0.000	0.000	6.000	7.000

(U) This program will develop a new generation of CAD tools to enable the design of integrated three-dimensional electronic circuits. The program will focus on methodologies to analyze and assess coupled electrical and thermal performance of electronic circuits and tools for the coupled optimization of parameters such as integration density, cross talk, interconnect latency and thermal management. The deliverables from this program will have a significant impact on the design of mixed signal (digital/analog/RF) systems and Systems-on-a-Chip for high performance sensing, communication and processing systems for future military requirements.

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

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	FY 2002	FY 2003	FY 2004	FY 2005
Chip-to-Chip Optical Interconnects	0.000	0.000	3.000	5.000

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

(U) Program Plans:

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

	FY 2002	FY 2003	FY 2004	FY 2005
Advanced Photonic Circuits	0.000	0.000	3.000	5.815

(U) This program will develop two critical alternative photonic technologies based on silicon substrates. The first thrust addresses active photonic components based on silicon which do not rely on generating light within the material. While passive photonic components, such as waveguides, can be fabricated from silicon, silicon's indirect bandgap does not lend it to fabricating active photonic components based on the generation of photons (lasers, amplifiers etc.). The first alternative technology development will be optical amplifiers using Raman gain. Fiber amplifiers based on Raman gain currently play a major role in optical networks, and demonstrating this optical amplification in silicon will be a major step toward overcoming on chip losses in complex chip-scale optical components. The second alternative technology development will address optical transistor action, or switching, in silicon, (i.e., a three-terminal optical device, in which control photons at one terminal will make a

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large change in the photons transmitted between the other two terminals). Taken together, these two capabilities will create a new paradigm, in which silicon will provide a platform for monolithic integration of photonic and electronic functions.

(U) Program Plans:
- Demonstrate low-loss waveguides connecting optical gates.
- Demonstrate increased dynamic range for the logic gates.
- Demonstrate integrated processing functions such as adders and shift registers, requiring integration of 3-10 logic gates.

	FY 2002	FY 2003	FY 2004	FY 2005
High Frequency Wide Band Gap Semiconductor Electronics Technology	24.150	20.431	19.970	16.000

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

(U) Program Plans:
- Develop bulk and surface process technologies for reducing or mitigating crystallographic defects in wide band gap materials.
- Develop semi-insulating substrates for high frequency devices.
- Design high power enclosures for microwave electronic assemblies.
- Demonstrate large periphery high power devices suitable for microwave and mm-wave operation.
- Demonstrate process reproducibility and minimization of yield limiting factors.
- Establish device characterization for very high power solid-state amplifiers.
- Demonstrate 100 mm SiC and wide band gap alternate substrates with less than 80 micropipe/cm^2 and resistivity 10^6 ohms-cm.
- Demonstrate epitaxial processes that yield + 3 percent uniformity over 75 mm wide bandgap substrates.
- Initiate thermal management study to determine best packaging approach for high power, high frequency microwave and millimeter wave transistors.

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

	FY 2002	FY 2003	FY 2004	FY 2005
High Power Wide Band Gap Semiconductor Electronics Technology	11.951	7.999	12.140	14.000

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

(U) Program Plans:

- Develop low defect conducting Silicon Carbide (SiC) substrate consistent with yielding 1 cm^2 devices.
- Develop lightly doped, thick (more than 100 micron) SiC epitaxy with low defects to enable 10 kV class power devices.
- Develop low on-state resistance SiC diodes capable of blocking 10 kV.
- Demonstrate SiC wafer and thick epitaxy with less than 1.5 catastrophic defects per cm^2 consistent with 10 kV reverse blocking.
- Initiate work on Megawatt class SiC power device able to switch at more then100 kHz.
- Initiate work on packaging of high power density, high temperature SiC power electronics.
- Demonstrate megawatt Class SiC power devices.
- Demonstrate high power density packaging for greater than 10 kV operation.
- Develop integrated power control logic compatible with high temperature and power SiC power devices.

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	FY 2002	FY 2003	FY 2004	FY 2005
Smart Power Based On Heterogeneous Integration of Si and SiC Electronics	0.000	0.000	6.686	8.000

(U) The Smart Power Based on Heterogeneous Integration of Silicon and Silicon Carbide Electronics program will develop the technology to monolithically or heterogeneously integrate Si/SiGe-on-SiC and/or SiC-on-Si/SiGe, develop new device and circuit concepts to optimize converter performance, and develop optimized kW-class power converters for various of DoD electronics applications.

(U) Program Plans:

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

	FY 2002	FY 2003	FY 2004	FY 2005
Acoustic Micro-Sensors	5.802	0.000	0.000	0.000

(U) The Acoustic Micro-Sensors program demonstrated a miniature acoustic sensor system based on MEMS transducers and advanced non-linear signal processing techniques for three-dimensional detection, capture, and tracking of sound sources in noisy environments with optimum sensitivity.

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(U) Program Plans:
- Integrated MEMs-based three-dimensional acoustic transducer array with read-out electronics.
- Demonstrated acoustic microsystem for remote detection and tracking of voices or sound sources in noisy outdoor environments.

	FY 2002	FY 2003	FY 2004	FY 2005
Materials Integration on Silicon	7.997	0.000	0.000	0.000

(U) The Materials Integration on Silicon program demonstrated technologies and applications of direct integration of advanced materials and devices, such as high-speed logic and RF transistors with semiconductor integrated circuits.

(U) Program Plans:
- Demonstrated heterogeneous fabrication processes and technologies for integrating disparate semiconductor devices and materials.
- Completed fabrication of composite microcircuits that demonstrate advanced capabilities through the incorporation of devices from multiple materials.
- Evaluated feasibility of flexible, mobile, high-resolution display components for wireless communications.

	FY 2002	FY 2003	FY 2004	FY 2005
Reconfigurable Aperture (RECAP)	6.236	0.000	0.000	0.000

(U) The Reconfigurable Aperture (RECAP) program provided revolutionary antenna technology for future military needs in high capacity communications and sensors. Technologies advanced include: artificial magnetic conductors, radio frequency (RF) MEMS switches, photonic band gap ground planes, high-density multi-layer interconnects and fragmented antennas. These were integrated into demonstrations that showed substantial new capabilities such as multi-beam arrays for communication and multi-band radar links that electronically reconfigure to provide near-hemispherical coverage. Applications such as the Future Combat System need such battlefield links. Wideband antenna technologies allow simultaneous Electronic Support Measures and radar functions from a single aperture. Finally, this technology allows the number of antennas on aircraft and ships to be reduced by a factor of 5 – 10.

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(U) Program Plans:
- Integrated and assembled component technologies into single sub arrays, which replace multiple antenna systems.
- Developed and demonstrated low cost fabrication processes to support technology transition.
- Initiated demonstrations of applications in low band communications, ELINT/SIGINT and multiband radar.
- Completed validation of Renoir modeling and simulation software.
- Used Renoir model to estimate impact of RECAP technologies on existing and future antenna systems.
- Completed demonstrations.

	FY 2002	FY 2003	FY 2004	FY 2005
Fabrication of 3D Structures	1.400	2.341	0.000	0.000

(U) The Fabrication of Three Dimensional Structures program investigated multi-chip module technology.

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

	FY 2002	FY 2003	FY 2004	FY 2005
Center for Optoelectronics and Optical Communications	2.000	4.876	0.000	0.000

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

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

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	FY 2002	FY 2003	FY 2004	FY 2005
Center for Integrated Technologies (CIT)	5.000	0.000	0.000	0.000

(U) The Center for Integrated Technologies (CIT) program focused on basic and applied research outcomes to incubate new and existing commercialization opportunities of photonic devices and materials. CIT will support the vision to be a catalyst for promoting sustainable economic development and growth in Western North Carolina. The long-term objective is aimed at photonics manufacturing focusing on design for manufacturability, quality, reliability of devices, increased producibility, and increased yields of devices and components.

(U) Program Plans:
- Created an undergraduate program for training technical manpower needed for volume manufacturing of advanced photonic components.
- Developed designs for fiber optic connectors that are capable of submicron precision and yet are amenable to volume production at very low cost.
- Developed designs for the next generation (for 10 G Ethernet) optical transmitter/receiver modules.

	FY 2002	FY 2003	FY 2004	FY 2005
Boron Energy Cell	2.000	0.000	0.000	0.000

(U) The Boron Energy Cell effort investigated the use of Boron Energy Cell technology that uses radiation hardened semiconductor materials and radioactive isotope energy sources to support advanced DoD technology applications in long duration power generation and self-powered electronics.

(U) Program Plans:
- Developed the science and technology base for boron energy cells.

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	FY 2002	FY 2003	FY 2004	FY 2005
Nanostructured Photonic and Biomedical Materials	0.000	0.974	0.000	0.000

(U) Program Plans:

– Self assembly chemistry will be used to prepare new materials for applications in spintronics and bio-inspired optics.

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

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Cryogenic Electronics MPT-06	7.823	4.149	4.911	9.808	14.678	16.611	19.523	19.504

(U) **Mission Description:**

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

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

	FY 2002	FY 2003	FY 2004	FY 2005
Totally Agile Sensor Systems (TASS)	7.823	4.149	0.000	0.000

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

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selectivity, by narrowing the bandwidth of the HTS filter by 10-100X, while maintaining tunability. Such capability will vastly improve overhead SIGINT collection in a spectrally-crowded environment.

(U) Program Plans:
- Fabricate novel HTS filters with ultra-high quality factor (Q) and 0.1% bandwidth.
- Incorporate agile front-end pre-selector modules utilizing tunable high-Q HTS filters within standard receivers.
- Demonstrate totally agile sensor systems with ten times SIGINT and COMINT capability.
- Transition capability for 30 percent tunability to RC-135 aircraft demonstration.
- Adapt ultra-high Q and tunability for demonstration in a receiver console, with features for sweep rate and filter reconfiguration.

	FY 2002	FY 2003	FY 2004	FY 2005
Rapid Identification and Targeting (RAPIT)	0.000	0.000	4.911	9.808

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

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

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

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

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Beyond Silicon MPT-08	63.511	88.459	78.871	47.826	19.570	14.657	0.000	0.000

(U) Mission Description:

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

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

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Quantum Information Science and Technology (QuIST)	15.386	20.597	27.268	23.879

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

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decoherence, limited communication distance due to signal attenuation, limited selection of algorithms and protocols, and scalability to large numbers of bits. Error correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Signal attenuation will be overcome by exploiting quantum repeaters. New algorithm techniques and complexity analysis will increase the selection of algorithms, as will a focus on signal processing. Scalable solid-state technologies will integrate thousands of qubits on a single device. Expected impacts include highly secure communications, algorithms for optimization in logistics and wargaming, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking.

(U) Program Plans:

- Determine quantum architecture and design solutions for problems such as graph isomorphism, imaging, and signal processing.
- Investigate alternative protocols for secure quantum communication, quantum complexity, and control.
- Investigate the use of quantum information in metrology.
- Demonstrate improved single and entangled photon sources and detectors.
- Investigate alternative designs, architectures and devices for quantum communication, computation, and memory; demonstrate low overhead, fault tolerant solid state quantum bit (qubit) memory and gates with at least two entangled qubits.

	FY 2002	FY 2003	FY 2004	FY 2005
Polymorphous Computing Architecture	13.266	14.942	16.992	13.574

(U) The Polymorphous Computing Architectures program is developing a revolutionary approach to the implementation of embedded computing systems to support reactive multi-mission, multi-sensor, and in-flight retargetable missions, and reduce payload adaptation, optimization, and verification from years to days to minutes. Current DoD embedded computing systems can be characterized as static in nature, relying on hardware-driven, heterogeneous point-solutions that represent static architectures and software optimizations. The program breaks the current development approach of hardware first and software last by moving beyond conventional silicon to flexible polymorphous computing systems. The key efforts of this revolutionary step forward in embedded computing systems are: 1) define critical reactive computing requirements and critical micro-architectural features; 2) explore, develop and prototype reactive polymorphous computing concepts; 3) explore, develop and prototype multi-dimensional verification and validation techniques for dynamic reactive missions; and 4) provide early experimental testbeds and prototype polymorphous computing systems. The result will be an embedded computing processing capability that will be mission and technology invariant yet highly optimizable for each new mission instantiation, thus providing for tactical and strategic mission tempo

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opportunities as well as technical upgradeability over the life of the computing system. Based on an average of four major upgrades over a 30 year period, significant saving of up to 45 percent in development and deployment costs may now be achieved over the life of a typical DoD embedded computing system.

(U) Program Plans:
- Characterize and perform functional decomposition of pivotal reactive system algorithms and computing functions.
- Develop multi-dimensional reactive computing optimization, verification techniques.
- Model, simulate and characterize complete candidate polymorphic computing systems including hardware elements, morphware, run-time systems, and tools.
- Perform early small scale proof-of-concept testing, integration and evaluation of early polymorphic computing architecture prototypes.
- Demonstrate and quantify the potential of full up polymorphic computing architecture systems for the DoD and their complementary commercial viability.
- Select, develop, and perform a DoD risk reduction effort for a multi-mission application.

	FY 2002	FY 2003	FY 2004	FY 2005
Antimonide Based Compound Semiconductors (ABCS)	10.979	14.870	9.346	0.000

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

(U) Program Plans:
- Substrate Technology. Accelerate recent breakthroughs in lateral epitaxial overgrowth and thin film delaminating and rebonding to develop a source for ABCS substrates with essentially any desired thermal and/or electronic property.
- Electronics Integration. Raise levels through a series of demonstrations of analog, digital or mixed signal circuits with increasing device count which have beyond state-of-the-art performance in terms of frequency of operation and low power consumption.
- Demonstrate robust semi-insulating ABCS substrate material.

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- IR sources. Exploit the unique bandgap engineering approaches available with the ABCS family of materials to increase the operation temperature above 230 degrees Kelvin and extend emission over the Long-Wave Infrared (LWIR) range.
- Achieve multi-watt output, array technology along with increases in efficiency for individual devices.
- Deliver first six multi-batch ABCS substrates.

	FY 2002	FY 2003	FY 2004	FY 2005
Integrated Mixed Signal (A/D) and Electronic/Phototonic Systems (NeoCAD)	10.857	15.529	8.987	0.000

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

(U) Program Plans:

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

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	FY 2002	FY 2003	FY 2004	FY 2005
Moletronics	13.023	22.521	11.330	0.000

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

(U) Program Plans:

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

	FY 2002	FY 2003	FY 2004	FY 2005
Molecular Computing	0.000	0.000	4.948	10.373

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

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(U) Program Plans:

- Construct combinatorial logic functions assembled from molecular-scale components.
- Use small-scale integration (SSI) to build combinatorial logic functions using molecular-scale components.
- Construct sequential logic/Finite-state machine assembled from molecular-scale components.
- Add registers or latches in communication with combinatorial logic arithmetic functions.
- Use medium-scale integration (MSI) to construct sequential logic/finite-state machine assembled from molecular-scale components.

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

- Not Applicable.

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COST (In Millions)	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Biologically Based Materials and Devices MPT-09	0.000	85.081	84.674	88.858	86.402	78.169	78.093	78.017

(U) Mission Description:

(U) This project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials and devices as well as the commensurate influence of materials, physics and chemistry on new approaches to biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials for enhancement of performance, the development of multifunctional transducers based on biological membranes, and the application of magnetic materials in biological applications. This project contains efforts originating in Projects MPT-01, MPT-02 in this PE and maturing technologies from PE 0601101E, Project BLS-01. For convenience, FY 2002 accomplishments for those efforts are presented in this project.

(U) Program Accomplishments/Planned Programs:

	FY 2002	FY 2003	FY 2004	FY 2005
Bioinspired and Bioderived Materials	0.000	35.081	33.000	32.758

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

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(U) Program Plans:

- Explore soft materials (e.g., actuators, adhesives) in biological systems for potential Defense applications.
- Demonstrate biomimetic sensory prototypes that collect electromagnetic olfactory and visual inputs.
- Define new materials for coordinated appendage function in land and air platforms that utilize biomimetic principles of locomotion and actuation.
- Explore new bioinspired locomotion in robotic systems and develop power efficient, systems level bio-locomotion for mobility in rough terrain.
- Demonstrate a material system based on bio-inspired optics technology that can produce a reversible change in the index of refraction of 1.0 point over a bandwidth of at least 50 nanometers with 95% or better transmittance allowing a re-configurable optical system that is capable of changing between wide angle (120 degrees) and narrow field of view within a frame rate.
- Develop bio-inspired optical components and filters based on novel materials chemistry and unique hierarchical structure.
- Determine and quantify the mechanism of motor function, motor performance, and efficiency for several types of biomolecular motors through computational models and experimental measurements.
- Isolate, modify, and integrate biomolecular motors with synthetic/inorganic materials to demonstrate devices with unique energy conversion capabilities and potential DoD utility.
- Exploit animal sentinels, including the development of critical materials/device interfaces to address teleoperation and autonomous navigation, for their ability to be remotely guided to operationally relevant sites and generate environmental information (chemical, biological, visual).

	FY 2002	FY 2003	FY 2004	FY 2005
Biochemical Materials	0.000	38.000	35.000	35.000

(U) The Biochemical Materials thrust examines how breakthroughs in the understanding of biochemistry can drastically improve the capabilities of soldiers. For example, examining the biochemistry of the brain during sleep deprivation can lead to new approaches in enhancing performance in soldiers. The application of biochemical principles can also lead to understanding the physiology of the solider as he/she heads for battle and to developing techniques to allow the principles of biological organisms that survive in extreme environments to be exploited for the preservation of tissue and cells of interest to DoD.

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(U) Program Plans:

- Demonstrate induced desiccation strategies for platelets that allow over 13 months of dry storage and recovery.
- Develop self-care medical technology to enable the warfighter in the battlefield to accelerate wound healing, internal clotting and pain relief to maintain a functional soldier.
- Develop an understanding of the biochemical and physiological causes of decreased cognitive performance during sleep deprivation through studying animal model systems, synaptic function, and transcranial magnetic stimulation (TMS).
- Demonstrate and validate approaches to develop biomaterials and other concepts that extend the cognitive performance capabilities of warfighters during extended periods of sleep deprivation and stress.
- Develop methods for enhancing functional and physiokinetic endurance by nutritional, pharmaceutical and physical methods that are rapidly inducible, reversible and minimize the need for caloric intake while enhancing both strength and endurance.
- Develop methods for regulating core body temperature that enhance physical performance and endurance.
- Demonstrate the capability to transfer biochemical processes chemically or physically to cells lacking robust survival mechanisms.
- Understand pathways and develop biomedical technology required to enhance spatial orientation of the warfighter.

	FY 2002	FY 2003	FY 2004	FY 2005
Responsive Membrane Devices (REMEDE)	0.000	7.000	5.674	3.500

(U) The goal of the Responsive Membrane Devices (REMEDE) program is to engineer biomimetic membrane technology and other biomimetic concepts necessary for the emulation of the critical biochemical functions found in nature. An important underlying technology supporting this thrust is the ability to rapidly identify the underlying biological materials and structures, particularly the ability to rapidly identify DNA/RNA/protein structures for potential use or optimization in subsequent processes. Specifically, this program will develop and demonstrate approaches for manufacturing a variety of materials (proteins, polymers, etc.) with the specificity found in nature at the scale of manufacture useful for Defense.

(U) Program Plans:

- Develop membrane based, micro-reactors and related nanotechnologies that will emulate and scale up the precise biochemical and chemical processes capabilities of biology.
- Demonstrate the production of ultra-high purity materials of interest to DoD including proteins and organic compounds.

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– Demonstrate feasibility of single molecule DNA/RNA/protein sequencing towards a tool for bioinspired materials and process engineering.

	FY 2002	FY 2003	FY 2004	FY 2005
Bio-Magnetic Interfacing Concepts (BioMagnetICs)	0.000	5.000	6.000	8.000

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

(U) Program Plans:

– Develop and demonstrate a portable, magnetics-based DNA detection and readout capability for human identification and biodetection.
– Develop and demonstrate a capability for non-invasive, non-destructive imaging of intracellular activity.
– Develop and demonstrate remotely addressable, magnetics-based biochemical sensors.
– Develop and demonstrate the capability to magnetically manipulate and actuate cellular functions such as apoptosis, reproduction, and gene expression.
– Develop and demonstrate the capability to use magnetics to rapidly filter biotoxins from humans.

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	FY 2002	FY 2003	FY 2004	FY 2005
Energy from Bio Systems	0.000	0.000	5.000	9.600

(U) The Energy from Bio Systems program will provide a power source for systems requiring long-term operational endurance as well as fast start-up times for systems that require immediate power. A liquid-fuel, biocatalytic fuel cell is being developed as one potential new energy source (for underwater applications in particular). Enzymes yield controlled reactions and products and recent advances in enzyme immobilization make them an attractive new electrode material. Many enzymes have kinetic constants orders of magnitude above metal catalysts for identical reactions, specifically with hydrogen peroxide and methanol.

(U) Program Plans:

- Identify methods of bioelectrocatalyst immobilization.
- Evaluate methods of mediator-less electron transport, and candidate molecules that act with peroxidase-like activity.
- Evaluate electrolyte-electrode-bioelectrocatalyst interactions and superstructures, and develop advancements in polymer science for electrode fabrication.
- Design bioelectrocatalysts that are compatible to both the environment of the fuel cell, the electrolyte, and electron transport to the electrode.
- Develop a proof-of-concept prototype biocatalytic (immobilized enzyme), liquid-phase fuel cell.

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

- Not Applicable.