RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)							DATE February 2002		
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research				R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, R-1 #20					
COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	255.026	344.554	440.500	550.126	594.165	612.074	631.442	Continuing	Continuing
Materials Processing Technology MPT-01	148.753	168.931	145.251	194.268	195.149	231.825	271.434	Continuing	Continuing
Microelectronic Device Technologies MPT-02	89.105	92.661	122.000	157.927	190.196	183.848	162.743	Continuing	Continuing
Cryogenic Electronics MPT-06	17.168	9.094	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Beyond Silicon MPT-08	0.000	73.868	94.999	84.700	66.173	43.194	39.453	Continuing	Continuing
Biologically Based Materials and Devices MPT-09	0.000	0.000	78.250	113.231	142.647	153.207	157.812	Continuing	Continuing

(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 Materials Processing Technology project concentrates on the development of 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 enable new missions for military platforms and systems as well as to increase human performance. Areas of concentration include exploitation of emerging processing approaches to tailor the properties and performance of structural materials and devices. This emphasis includes lightweight personnel protection, mesoscale machines for miniature devices, and ultra lightweight and amorphous materials. Approaches for materials risk reduction will also be explored. The project also focuses on smart materials, sensors and actuators, functional materials and devices,

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advanced magnetic materials for non-volatile, radiation hardened magnetic memories, and electroactive polymers for sensing and actuating. Other areas of concentration include new materials concepts for portable power, development of bio-interface materials and methods, energy harvesting concepts, and frequency agile materials based on ferrite and ferroelectric oxides. Electronics Textiles will develop new technologies and manufacturing techniques for economic manufacture of large-area, flexible conformable information systems. This project also includes a biological systems thrust. The unique characteristics of biologically derived functional materials and devices will be exploited through the understanding and control of the structure and chemistry of the interface between man-made and biotic materials. In addition, emulation and/or control of biological functionality (i.e., sensing and mobility) will be explored for enhanced DoD applications (sensor, robotic, etc.). Biologically Based Materials and Devices programs transfer to Project MPT-09 beginning in FY 2003.

(U) The Microelectronics Device Technologies project supports the continued advancement of microelectronic device technologies (digital, analog, photonic and micro-electromechanical) 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. Areas of emphasis include high-performance analog-to-digital converters, military optical processors, novel integrated optoelectronic devices and components, high temperature electronic devices, and high power electronics. Additionally, this project will focus on advanced microelectronics technologies such as digital radar receivers and acoustic-electronic components; optical signal processing of military RF waveforms; and high frequency/high power wide band gap semiconductor technologies. The project also initiated a significant effort to develop advanced materials and device technology beyond the classical scaling limits of silicon device technology. These efforts transferred to project MPT-08 in FY 2002.

(U) The Cryogenic Electronics project funds specific applications of thin-film electromagnetic materials in electronic devices and circuitry for military applications. Thin-film high temperature superconducting components packaged with cryogenic devices are being applied to radars, electronic warfare suites, and communications systems to enhance performance while reducing size and power requirements. Highly dependable and inexpensive cryocoolers (including thermoelectric coolers) are being developed for these applications, and expanded efforts will explore techniques to improve the performance of all solid-state thermoelectric coolers as well as the overall cryogenic performance in applications ranging from communications to computing.

(U) The Beyond Silicon project is investigating the feasibility, design, and development of powerful information technology devices and systems using approaches to electronic device designs that extend beyond traditional Complementary Metal Oxide Semiconductor (CMOS) scaling, including non-silicon based materials technologies, to achieve low cost, reliable, fast and secure computing, communication, and storage systems.

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

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

	FY 2001	FY 2002	FY 2003
FY02 Amended President's Budget	261.883	358.254	298.875
Current Budget	255.026	344.554	440.500

(U) Change Summary Explanation:

FY 2001 Decrease reflects the SBIR reprogramming.

FY 2002 Decrease reflects congressional program reduction partially offset by several Congressional Adds in MPT-01 and MPT-02.

FY 2003 Increase reflects the continuation of the High Power Electronics/Wide Band Gap program and the initiation of Adaptive Focal Plane Arrays, Vertically Interconnected Sensor Arrays and Ultra-High Speed Digital Circuit Technology programs (MPT-02) and the new project, Biologically Based Materials and Devices (MPT-09).

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Materials Processing Technology MPT-01	148.753	168.931	145.251	194.268	195.149	231.825	271.434	Continuing	Continuing

(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.

(U) One important area of concentration is the exploitation of emerging processing approaches to tailor the properties and performance of structural materials and devices. 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 using 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.

(U) The mesoscopic size range ("sugar cube to fist") offers significant advantages in devices for defense. Efforts include mesopumps for battlefield sensors and mesocoolers for the individual soldier and water lubricated, energetic mesoengines. 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.). Mesoscale materials technologies will also be employed in novel approaches for obtaining and purifying water in the field.

(U) 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. "Intrinsically smart" materials that provide self-diagnosis and/or self-repair will be developed as well. Machines are being developed that would increase soldiers physical capabilities 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.

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(U) Another major thrust is 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. Frequency-agile materials based on ferrite and ferroelectric oxides are being developed for tuned filters, oscillators, and antennas. 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. Finally, new techniques will be developed for atomic level resolution probing of defect densities and composition profiles in semiconductors and other novel materials.

(U) The unique characteristics of biologically inspired and biologically derived materials and devices will be exploited 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 will move to a new project, MPT-09 in FY 2003 to acknowledge the growing and pervasive influence of biological science on the development of new materials and devices.)

(U) 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 investigated.

(U) The Electronics Textiles (e-Textiles) program will develop a revolutionary new integrated electronic and textile technology capability base and industry by leveraging the formerly independent electronic and textile industries. The underlying conceptual advance or enabling technology is the development and insertion of electronic mixed signal yarns and textiles into everyday fabrics and fabric-based infrastructures. As a result, textiles will have the revolutionary ability to sense, act, store, emit, and move while leveraging an existing low cost textile-manufacturing infrastructure. This new cabability will enable the integration of many formerly discrete physical devices/packages and functions into a

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compressible, homogeneous, intelligent textile system that will support rapid field deployment and adaptation plus provide a new set of revolutionary war fighting capabilities such as covert sensing, intelligent decoys, smart uniforms, and space sails and antennas.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Structural Materials and Devices. ($26.435 Million)
  - Demonstrated concepts for ultra-lightweight armor with 100 percent improvement over current materials and began full-scale testing.
  - Demonstrated the use of multifunctional materials to provide significant improvement in the capabilities of defense systems by providing additional functions (e.g., self-healing, thermal control, blast protection, power) to load bearing structures.
  - Continued the optimization of analytical, experimental and simulation technologies for determining the properties and processing of advanced polycrystalline, nanocrystalline and amorphous materials.
  - Selected specific material(s) of high value to a DoD system for demonstration of accelerated insertion concepts.

- Mesoscopic Structures and Devices. ($14.200 Million)
  - Demonstrated initial, one-dimensional mesoscopic gyroscope operation that has drift rates less than one degree per hour.
  - Demonstrated fully functional integrated mesoscopic coolers that exhibit a coefficient of performance greater than three.
  - Demonstrated that direct-write mesoscale active and passive components have functionality close to discrete surface mount components.
  - Demonstrated the ability to direct-write mesoscale passive components (resistors, capacitors) and antennas on conformal surfaces.
  - Explored energetic machines and devices that aid the soldier in urban terrain.

- Smart Materials and Actuators. ($25.800 Million)
  - Completed wind tunnel test verification of an active aircraft engine inlet enabling a 20 percent increase in aircraft mission radius compared to a conventional fixed geometry inlet design.
  - Completed water tunnel test of a subscale submarine propulsor with active control to reduce acoustic radiation levels.
  - Explored techniques that use the intrinsic response of a material to its operating environment to provide diagnosis of the performance life of the material.

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- Developed approaches for integrating actuators, power systems and control methods to affect lightweight, energy efficient actuators for enhancing the performance of soldiers.
- Investigated artificial materials and membranes that can be integrated into controllable variable porosity fabric.
- Demonstrated methods to fabricate multilayer actuators made from single crystals of relaxor piezoelectrics.
- Demonstrated the performance of single crystal piezoelectrics in an advanced Navy sonar transducer.

- Functional Materials and Devices. ($40.836 Million)
  - Demonstrated a prototype, very high effective density (greater than 16 Mbit), high speed (less than 10 nsec access time) magnetic memory circuit based on giant magneto-resistance (GMR) or spin-dependent tunneling utilizing very low power and low voltage (less than 2.5 volts).
  - Demonstrated a steerable, ferroelectric lens for phased array radar.
  - Demonstrated a conformal, frequency agile antenna that is 100 times cheaper than conventional technology.
  - Explored applications of metamaterials for advanced electromagnetic devices (e.g., antennas).
  - Demonstrated advantages of polymer-based actuators in specific Defense applications (e.g., robotics, sonar, BW sensors).
  - Demonstrated the use of electroactive polymers as thin-film spatial filters for quasi-real-time multispectral image analysis for enhancing target detectability.
  - Investigated various multi-chromal fabrics that can be integrated along with conventional fabrics and be used to display information to a soldier on the uniform.

- Bioinspired Materials and Devices. ($7.082 Million)
  - Identified candidates for advanced sensor systems that incorporate biologically inspired concepts including self-calibration, self-healing, variable temperature operation, functional responsiveness and mobility.
  - Constructed prototype microelectronic interfaces for control of biological systems.

- Advanced Energy Technologies. ($16.900 Million)
  - Demonstrated energy harvesting from the environment for unattended sensor and soldier applications.
  - Demonstrated high efficiency direct thermal to electric energy conversion operating on a liquid hydrocarbon fuel.
  - Developed specific approaches for small, chemical power generation that operates at near ambient temperatures.

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- Investigated novel ultra-high energy density power source concepts.

- Bio: Info: Physical Systems Interface. ($5.000 Million)
  - Created new families of catalysts and pathways for synthesizing compounds and materials biomimetically.
  - Explored new architectural components and assembling principles of biological systems; developed new artificial matrices and assembling processes.
  - Developed new materials and matrices for sensing, actuation and computation via biologically inspired routes to material synthesis.

- Materials in Sensors. ($9.500 Million)
  - Continued work in materials and processing, including investigation of novel polymer and inorganic sensor and sensor protection schemes based on electroactive polymer and carbon nanotubes.

- Strategic Material Manufacturing. ($3.000 Million)
  - Continued to develop new manufacturing approaches for cutting tools and other ceramics used for Defense applications.

(U) FY 2002 Plans:

- Structural Materials and Devices. ($32.500 Million)
  - Evaluate concept for ultra-lightweight armor materials in a system with 100 percent improvement over currently fielded systems; transition to Army.
  - Identify models and mathematical techniques for capturing the physics of failure and behavior prediction in materials suitable for providing information on the degree of in-situ damage accumulation.
  - Demonstrate solutions to critical technical issues for the accelerated insertion of materials, quantifying potential payoff (time and resources) of each. Begin the integration of these technologies into a methodology that will allow designers to cut the insertion time of new materials by over 50 percent.
  - Quantify the performance of multifunctional structures that combine structure with additional functions, significantly reducing the parasitic weight of the structure in defense systems. Specific functions to be demonstrated include: self-healing, power generation, and self-sensing.

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- Develop and verify models that predict bulk amorphous metal formation; describe the deformation behavior of structural amorphous metals. Use these models to produce bulk amorphous materials with superior properties as compared to crystalline materials, including increased fracture toughness and high strain rate behavior.
- Investigate novel, cost effective processing routes for structural materials of interest to Defense (e.g., Ti).

- Mesoscopic Structures and Devices. ($20.200 Million)
  - Demonstrate the ability to "dial-in" any passive component with at least five percent tolerances with direct-write electronics manufacturing tool.
  - Fabricate direct-write batteries on complex geometries.
  - Demonstrate two-dimensional patterning of two cell types with the associated microelectrode array using direct-write.
  - Fabricate high efficiency direct-write antennae on low-temperature substrates.
  - Investigate concepts for highly power-dense, portable mesoscale machines and devices that aid the soldier in urban terrain.
  - Evaluate concepts for obtaining water from non-traditional sources.
  - Model and evaluate concepts to desalt brackish water with low energy.

- Smart Materials and Actuators. ($29.992 Million)
  - Demonstrate the utility of smart materials and adaptive structures in military platforms.
  - Complete flight test of a rotorcraft with blades containing integral actuators and flaps for control of noise and vibration.
  - Develop concepts that exploit smart materials to create new high power actuators for a variety of military platforms.
  - Demonstrate energy efficient electronics for smart actuator systems.
  - Demonstrate integrated power and actuation systems that exploit energy dense fuels.
  - Develop models that describe the dynamic performance required from actuators to augment soldiers in a variety of mission scenarios.
  - Explore system architectures for enhancing soldier physical performance including lower extremities for locomotion augmentation and upper extremities for strength augmentation.

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- Demonstrate pilot production technology for piezocrystals in quantities and at cost suitable for prototype devices.
- Demonstrate, on laboratory scale, targeted Naval sonar device/system performance using piezocrystals.
- Investigate advantages and enabling capabilities created by allowing shape change to occur in military platforms.

- Functional Materials and Devices. ($38.530 Million)
  - Demonstrate rad hard embedded magnetic random access memory for insertion into space and missile platforms.
  - Demonstrate prototype frequency and phase agile antennas and filters for transition to radar and communication systems.
  - Demonstrate embedded magnetoresistive non-volatile radiation hard memory for reconfigurable processors.
  - Investigate the electronic capabilities (sensors, transistors, etc.) of electronic polymers in Defense applications.
  - Demonstrate use of electroactive polymers in color displays, including flat panel and real three-dimensional displays.
  - Demonstrate exchange-biased ferromagnetism in a bulk material.
  - Develop processing approaches for low-cost manufacturing of high-performance printed optics (e.g., gradient index lenses).
  - Demonstrate/validate “left-handed” wave propagation at microwave frequencies.
  - Demonstrate low-power, compact, acoustic imaging beamformer technology with a large number of channels (more than 1,024).
  - Demonstrate 1.5 dimension acoustic imaging array technology with a large number of elements (more than 1,024).
  - Develop mathematical methodology for predicting macroscopic material characteristics from unit cell properties.
  - Explore new methods for imaging defect and composition profiles in novel materials.

- Bioinspired and Bioderived Materials and Devices. ($14.251 Million)
  - Demonstrate new capabilities in functionalizing magnetic nanoparticles for integration with biological hosts.
  - Evaluate alternative biological energy sources for driving biomolecular motors.
  - Isolate, modify and integrate biomolecular motors with man-made materials as a first step in developing devices with unique energy conversion capabilities and potential DoD utility.
  - Explore soft materials (e.g., actuators, adhesives) in biological systems for potential Defense applications.
  - Define new materials for coordinated appendage function in land and air platforms that utilize biomimetic principles of locomotion and actuation.
  - Demonstrate biomimetic sensory prototypes that collect electromagnetic, olfactory and visual inputs.
  - Identify genes that are responsible for stable biomaterials from organisms that survive environmental extremes.

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- Explore multifunctional materials from organisms that survive environmental extremes and define design principles for biomimetic materials development.
- Develop reduced-order mathematical control techniques for biochemical materials growth process.
- Identify biomaterials and processes that are associated with stress reduction and extended physical and medical performance on the battlefield.

- Advanced Energy Technologies. ($20.558 Million)
  - Fully integrate and demonstrate energy harvesting technologies with military applications.
  - Explore novel approaches for power generation based on sonoluminescence and related technologies.
  - Fabricate and test new direct methanol membrane electrode assemblies based on materials breakthroughs in membranes and catalysts.
  - Design a second-generation portable direct methanol fuel cell with 50 percent higher performance than the first generation.
  - Demonstrate direct electrochemical oxidation of hydrocarbon fuels at moderate temperatures in a single cell solid oxide fuel cell suitable for a hand-held system.
  - Develop concepts for hand-held hydrocarbon-fueled portable power sources in the 20-watt power range for advanced soldier systems.
  - Demonstrate high performance thermoelectric, thermionic or other direct thermal power generation and/or cooling devices for military and commercial applications.
  - Evaluate undersea energy sources for in-situ harvesting, processing, and use in undersea platforms and vehicles.

- Electronic Textiles. ($7.000 Million)
  - Initiate the design of novel fiber based active and passive components.
  - Weave, knit and/or braid components into test structures and develop electrical interconnection and physical mounting schemes.
  - Analyze performance characteristics of the components, structural and subsystem integrity including routing, buss structures and interconnection schemes to demonstrate the feasibility of incorporating the components into woven circuitry.
  - Evaluate requirements and implementation characteristics for large area applications comprised of novel materials and micro-systems.

- Advanced Materials, Frequency Tunable Materials. ($1.500 Million)
  - Investigate nano particles for the fabrication of frequency tunable materials and components.

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- Strategic Material Manufacturing. ($3.400 Million)
  - Continue development of new manufacturing approaches for cutting tools and other ceramics used for Defense applications.

- Detection and Destruction of CW-Nanotechnology. ($1.000 Million)
  - Develop technologies for detection and destruction of chemical weapons using nanostructured materials.

(U) FY 2003 Plans:

- Structural Materials and Devices. ($33.000 Million)
  - Validate, using existing designer data that the accelerated insertion methodology will cut the insertion time of a new material by over 50 percent. Initiate the application of the methodology to new materials that, if inserted, will significantly improve Defense systems.
  - Fabricate prototype systems that demonstrate the value of multifunctional materials to Defense applications.
  - Demonstrate the use of a multifunctional material as structure plus battery for a micro air vehicle.
  - 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.
  - Quantify the impact of using bulk amorphous materials in construction of land vehicles and naval vessels.
  - Integrate models and sensor data into a system for 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 process routes to structural materials of interest to Defense, including bronze castings for Navy application.
  - 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.
  - Demonstrate the microfabrication technology for amorphous metal MEMS devices and fabricate structures for evaluation.

- Mesoscopic Structures and Devices. ($15.000 Million)
  - Demonstrate the ability to direct-write semiconductor solar cells on low-temperature substrates.
  - Demonstrate the ability to direct-write robust embedded sensor systems with the physical structure along with appropriate encapsulation.

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- Demonstrate the ability to direct-write transistors, filters, and other active circuitry components economically, conformally, on low temperature substrates (plastics, kapton, etc.), and over large (greater than 12" x 12") areas.
- Explore techniques for patterning and/or altering the electromagnetic and structural properties of large area surfaces.
- Fabricate, using direct-write approaches, a three-dimensional pattern of two cell types in three-dimensions to mimic endothelial cells and smooth muscle cells.
- Demonstrate mesoscale energetic devices that create mechanical energy efficiently from chemical fuel sources utilizing precision fluidic controls, enabled by smart materials and MEMS.
- Demonstrate active membrane control for improved water flux and quality.
- Mitigate biological fouling of desalting membranes.
- Proof of concept demonstrations for water from air; test and evaluate optimized humidity concentration.

- Smart Materials and Actuators. ($31.000 Million)
  - Develop novel fluidic and mechanical systems to transmit energy from driver smart materials.
  - Using experimentally verified models, simulate the use of compact hybrid actuators for applications to military platforms.
  - Demonstrate man-machine interfaces that generate command signals and actuation from human physiological response.
  - Demonstrate man-wearable, powered actuation systems suitable for integration with the soldier.
  - Demonstrate an integrated, powered system for augmenting the locomotion and strength of soldiers using precisely controlled actuators and haptic interfaces that will link powered actuation to a soldier's movements.
  - Demonstrate, on field scale, targeted Naval sonar device/system performance using piezocrystals.
  - Develop devices and design structures that allow for morphing of structural systems during missions.
  - Model the performance gains of morphing structures within the context of a variety of concepts of operations for military platforms.
  - Initiate materials development efforts that will provide controllable shape changing systems that will ultimately increase the performance of air and space vehicles.

- Functional Materials and Devices. ($30.251 Million)
  - Demonstrate bulk meta materials with exchange biased permanent magnets with energy product greater than 60 megagausoersteds at room temperature.
  - Demonstrate novel properties of "left-handed" materials (e.g., negative Doppler shift).

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- Demonstrate meta material advantage in developing effective media with high permeability and low loss at microwave frequencies.
- Demonstrate the ability of an electroactive polymer to perform muscle-like sensing and actuation in Defense robotic applications.
- Demonstrate quantitative advantages of using the electronic capabilities (sensors, transistors, etc.) of electroactive polymers in Defense applications.
- Demonstrate performance of printed optics suitable for defense sensor applications (visible and/or infrared).
- Demonstrate rectification of microwave signal using metamaterial rectenna.
- Continue demonstration of low-power, compact, acoustic imaging beamformer technology with a large number of channels (more than 1,024).
- Continue demonstration of 1.5 acoustic imaging array technology with a large number of elements (more than 1,024).
- Demonstrate a novel technique for determining defect density and composition profiles of semiconductors and other novel materials.
- Explore the mechanisms of phonon engineering for enhancing transport properties in organics.

- Electronic Textiles. ($14.000 Million)
  - Develop and evaluate early prototypes of novel fiber based active and passive components.
  - Initiate yarn circuit analysis and textile circuit modeling efforts.
  - Perform yarn-to-yarn connectivity experiments.
  - Fabricate test samples of woven electronic circuits for characterization.
  - Demonstrate a discrete functional electronic textile for a selected DoD large area application.

- Advanced Energy Technologies. ($22.000 Million)
  - Demonstrate a portable direct methanol fuel cell system with 50 percent higher performance than the first generation.
  - Fabricate and test components for hand-held direct hydrocarbon energy conversion devices.
  - Demonstrate a 40-watt solid oxide fuel cell stack with internal reforming of hydrocarbon fuel.
  - Design and fabricate 20-watt hand-held direct hydrocarbon energy conversion devices for advanced soldier systems.
  - Develop extracting and processing technologies for undersea energy sources for stationary and mobile platforms.
  - Design a small, safe, nuclear driven compact power sources.
  - Demonstrate enabling direct thermal to electric conversion technologies with potential for high (better than 20 percent) conversion efficiencies and high (greater than 2 W/cm^2) power densities for DoD applications in electric drive and/or propulsion.

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- Develop power source and other concepts based on acoustically driven systems.
- Develop the technology base for small, safe, nuclear driven compact power sources.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research				R-1 ITEM NOMENCLATURE Materials and Electronics Technology PE 0602712E, Project MPT-02					
COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Microelectronic Device Technologies MPT-02	89.105	92.661	122.000	157.927	190.196	183.848	162.743	Continuing	Continuing

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

(U) The Acoustic Micro-Sensors program goal is to demonstrate 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.

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

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(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) Included within this project are several initiatives that began in FY 2002 including the Analog Optical Signal Processing Program, TEAM, the Chip Scale Atomic Clock and two Wide Band Gap Semiconductor programs.

(U) Analog Optical Signal Processing (AOSP) will significantly enhance the performance of, and enable entirely new capabilities/architectures for, tactical and strategic RF systems by expanding the dynamic range-bandwith 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) Technology for Efficient, Agile Mixed Signal Microsystems (TEAM) will enable fabrication of high performance mixed signal systems-on-chip (SoC) that will be the core of the embedded electronics in new platforms that are constrained by size and on-board power.

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

(U) High Frequency Wide Band Gap Semiconductor Electronics Technology will develop wide band gap semiconductor technology and 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) 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) Four new initiatives are budgeted in FY 2003 including the Ultra High-Speed Digital Circuit Technology program, a Phase II effort for Wide Band Gap Semiconductors, the Adaptive Focal Plane Array effort, and VISA – Vertically Interconnected Sensor Arrays.

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(U) The Ultra High Speed Digital Circuit Technology program will demonstrate the application of Indium Phosphide compound semiconductor materials for high speed circuit application to digital signal synthesizer and related signal processing applications.

(U) The Adaptive Focal Plane Arrays (FPA) program will develop and demonstrate infrared FPA that are electrically tunable, thus enabling real-time reconfiguration of the arrays for intelligent chip-scale sensing and imaging missions.

(U) The Vertically Interconnected Sensor Arrays (VISA) program will develop and demonstrate imaging readout technology, which will result in revolutionary improvement in the performance of Defense imaging systems. This will be accomplished through the development and implementation of novel three-dimensional imaging architectures, which emulate the visual process in living beings.

(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 initiative 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 designs, and other approaches to electronic device designs that extend beyond traditional Complementary Metal Oxide Semiconductor (CMOS) scaling to non-silicon based materials technologies. Given DoD emphasis in this area, the Beyond Silicon programs are funded in project, MPT-08, within this program element in FY 2002 and beyond.

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(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Reconfigurable Aperture (RECAP). ($13.459 Million)
  - Demonstrated fabrication and reconfigurability of fragmented antennas for wideband communication.
  - Constructed antennas with zero shift phase ground planes, switchable elements and polyimide materials for low cost component fabrication.
  - Continued successful core technologies and initiated efforts for integrated system application demonstrations concentrating on battlefield communications through low profile communications, space/air/surface/submarine-based electronic intelligence (ELINT), signal intelligence (SIGINT) and multiband radar systems.
  - Initiated validation of the RENOIR modeling and simulation tool (developed under the RECAP program) with experimental data.
  - Demonstrated dual polarization wideband antenna technology.

- Acoustic Micro-Sensors. ($5.557 Million)
  - Demonstrated MEMs-based 3-D acoustic transducers and transducer arrays with superior sensitivity, signal-to-noise ratio and bandwidth that are current state-of-the-practice.

- HERETIC. ($7.650 Million)
  - Demonstrated devices on GaAs having better specific heat-removal capacity as the best commercial-off-the-shelf thermo-electric coolers.
  - Demonstrated micro-jets, micro-nozzles, or micro-thermionic emitters on Si having much better heat-removal capacity as the best convective air or liquid cooling systems.

- 3-D Microelectronics. ($1.986 Million)
  - Continued development of key technologies behind a packaging concept that uses a stacked multi-chip module approach to reduce interconnect length and increase physical connectivity between layers of electronics.

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- VLSI Photonics. ($7.565 Million)
  - Demonstrated a Synthetic Aperture Radar (SAR) processor using VLSI Photonics technologies; showcased reconfigurable cross-connect switching.
  - Demonstrated rapid parallel access to memory using optical interconnection.

- Materials Integration on Silicon. ($8.484 Million)
  - Continued integration of new material and processes into a single silicon substrate that will drive system performance.
  - Demonstrated logic circuits and power amplifiers on silicon substrates.

- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($10.780 Million)
  - Continued component development, integration, algorithms, architectures and sub-system functionality demonstrations.
  - Demonstrated emitters and detectors in the spectral band 350-500 nm.

- Beyond Silicon - Antimonide Based Compound Semiconductors (ABCS). ($7.852 Million)
  - Demonstrated non-silicon based transistors technologies based on low band gap materials capable of multi-gigahertz operation at bias voltages less than one volt.
  - Demonstrated nanostructured materials for quantum based electronic and optoelectronic device applications.
  - Demonstrated a three terminal resonant tunneling device operating at several hundred GHz.

- Beyond Silicon - Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD). ($3.765 Million)
  - Developed fast algorithms for non-linear analysis of mixed signal systems – analog and photonic devices.
  - Extended algorithm methods to non-linear problems.

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- Beyond Silicon - Polymorphous Computing Architecture (PCA). ($7.714 Million)
  - Identified and selected DoD reactive in-mission and multi-mission applications of interest along with complementary commercial applications to ensure commercial viability.
  - Developed PCA hardware abstraction models and stable architecture framework.
  - Identified multi-dimensional reactive computing, communication, memory, verification and optimization techniques, and candidate implementations.

- Beyond Silicon - Quantum Information Science and Technology (QuIST). ($14.293 Million)
  - Investigated techniques for building reliable scaleable quantum bits out of devices potentially subject to failures and decoherence, via efficient fault tolerant mechanisms.
  - Investigated new problem classes, beyond factorization and unsorted search, which are solvable with dramatic efficiency on a quantum computer.
  - Initiated theory and algorithm research for secure quantum communication.
  - Investigated techniques amenable for implementation in existing networks and fiber optic backbone.

(U) **FY 2002 Plans :**

- Acoustic Micro-Sensors. ($4.073 Million)
  - Integrate MEMs-based 3-D acoustic transducer array with read-out electronics.
  - Demonstrate acoustic microsystem for remote detection and tracking of voices or sound sources in noisy outdoor environments.

- Materials Integration on Silicon. ($6.456 Million)
  - Complete technology development and demonstrations.
  - Demonstrate heterogenous fabrication processes and technologies for integrating disparate semiconductor devices and materials.
  - Complete fabrication of composite microcircuits that demonstrate advanced capabilities through the incorporation of devices from multiple materials.
  - Evaluate feasibility of flexible, mobile, high-resolution display components for wireless communications.

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- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($9.861 Million)
  - 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.

- Reconfigurable Aperture (RECAP). ($7.000 Million)
  - Integrate and assemble component technologies into single sub arrays, which replace multiple antenna systems.
  - Develop and demonstrate low cost fabrication processes to support technology transition.
  - Initiate demonstrations of applications in low band communications, ELINT/SIGINT and multiband radar.
  - Complete validation of RENOIR modeling and simulation software.

- Analog Optical Signal Processing (AOSP). ($7.212 Million)
  - 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 signal processing techniques of analog signals.
  - Evaluate signal-processing algorithms.
  - Evaluate photonic component performance requirements.

- Technology for Efficient, Agile Mixed Signal Microsystems (TEAM). ($6.309 Million)
  - 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.

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- Chip Scale Atomic Clock. ($4.350 Million)
  - Demonstrate feasibility and theoretical limits of miniaturization of cesium clock.

- High Frequency Wide Band Gap Semiconductor Electronics Technology. ($24.000 Million)
  - Demonstrate uniform growth of epitaxial wide band gap semiconductor films on substrates.
  - Develop bulk and surface process technologies for reducing or mitigating crystallographic defects in wide band gap materials.
  - Develop coupled electro thermal and physical models for design of high power device structures.

- High Power Wide Band Gap Semiconductor Electronics Technology. ($13.000 Million)
  - Develop electro thermal models for analyzing high power, high frequency enclosures.
  - Develop thermal management technologies for high power, high temperature devices.
  - Identify military system requirements and platform heat-management constraints.
  - Evaluate maximum thermal load capacity at the integrated circuit level.
  - Demonstrate effective high temperature adhesives and high power interconnect techniques.
  - Develop high frequency, high temperature passive components for integration with high power devices.

- 3-D Microelectronics. ($1.400 Million)
  - Continue development of key technologies behind a packaging concept that uses a stacked MCM approach to reduce interconnect length and increase physical connectivity between layers of electronics.

- Center for Optoelectronics and Optical Communications. ($2.000 Million)
  - Initiate optoelectronic and optical communications development.

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- Center for Integrated Technologies. ($5.000 Million)
  - Initiate photonic technology integration.

- Boron Energy Cell. ($2.000 Million)
  - Develop the science and technology base for boron energy cells.

(U) FY 2003 Plans:

- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP). ($10.561 Million)
  - Demonstrate integration with packaging module.
  - Demonstrate module in a testbed for bio-chemical sensing and spectral imaging.
  - Transition technology to DoD hypospectral/imaging programs and systems.

- Reconfigurable Aperture (RECAP). ($11.000 Million)
  - Use Renoir model to estimate impact of RECAP technologies on existing and future antenna systems.
  - Complete demonstrations.

- Analog Optical Signal Processing (AOSP). ($14.000 Million)
  - Design, fabricate and test individual photonic components capable of meeting RF signal processing requirements.
  - Determine the most promising approaches for development of integrated, chip-scale components using new materials and processing technologies.
  - Determine interface requirements.
  - Evaluate the suitability of the new components for use in prototype modules.
  - Down-select to the most promising approaches and begin prototype module assembly.
  - Construct testbeds capable of fully characterizing the photonic-based RF signal processing components.

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- Technology for Efficient, Agile Mixed Signal Microsystems (TEAM). ($12.000 Million)
  - 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 transitors.

- Chip Scale Atomic Clock. ($12.000 Million)
  - Demonstrate subcomponent fabrication, including atomic chamber, excitation and detection function.
  - Demonstrate design and fabrication innovation for atomic-confinement cell.
  - Demonstrate design and fabrication innovation for GHz resonators suitable for phase locking or direct coupling with atomic confinement cell.

- Wide Band Gap Semiconductor Electronics Technology. ($30.000 Million)
  - Develop semi-insulating substrate for high frequency devices.
  - Demonstrate control and activation of extrinsic dopants.
  - Develop a high quality oxidation process for application to metal-oxide-semiconductor (MOS) structures and demonstrate high carrier mobility in MOS structures.
  - Design low loss integration platforms for high power, high frequency operation.
  - Design high power enclosures for microwave electronic assemblies.
  - Demonstrate large periphery high power devices suitable for microwave and mm-wave operation, and large area power switches devices.
  - Develop RF materials and device designs.
  - Demonstrate high temperature operation of integrated power switches.
  - Demonstrate process reproducibility and minimization of yield limiting factors.
  - Establish device characterization for very high power solid-state amplifiers and power control devices.

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- Adaptive Focal Plane Arrays. ($11.000 Million)
  - Demonstrate next generation of imaging sensors providing multiple imaging functions on a single compact array suitable for the micro-systems planned for future combat platforms.
  - Focus on multi-band detectors with integral target discrimination and high operating temperature, matching or exceeding performance that is only available in large, more costly sensors.
  - Integrate heterogeneous detector materials to realize chip-scale hyper-spectral imaging.

- Vertically Interconnected Sensor Arrays (VISA). ($12.750 Million)
  - Implement highly parallel densely interconnected architectures with micron-sized vias penetrating stacks of detectors, analog, mixed signal and digital circuits.

- Ultra High Speed Circuit Technology. ($8.689 Million)
  - Initiate development of Indium Phosphide compound semiconductor materials for very high speed circuit applications.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile :

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Cryogenic Electronics MPT-06	17.168	9.094	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(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 and Plans:

(U) FY 2001 Accomplishments:

- Totally Agile Sensor Systems (TASS). ($17.168 Million)
  - Fabricated a cryogenic module, operating as a front-end pre-selector, to enhance the sensitivity of a receiver to detect low-level emitters in the presence of multiple interferors.
  - Designed a complete cryogenic receiver module, incorporating tunable HTS antenna/pre-selector and digital microelectronics (with HTS embedded passives), displaying unsurpassed sensitivity and interference rejection.

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(U) FY 2002 Plans:

- Totally Agile Sensor Systems (TASS). ($9.094 Million)
  - Incorporate agile front-end pre-selector modules on aircraft and ships, utilizing tunable high-Q HTS filters.
  - Demonstrate totally agile sensor systems with ten times SIGINT and COMINT capability.
  - Fabricate Thermoelectric modules that can be integrated with receiver front ends to provide cooling and/or thermal management as required for enhanced performance.
  - Transition capability for 30 percent tunability to RC-135 aircraft demonstration.
  - Adapt capability for tunability greater than 50 percent for demonstration in a receiver console, with features for sweep rate and filter reconfiguration.

(U) FY 2003 Plans:

- Not Applicable.

(U) Other Program Funding Summary Cost:

- Not Applicable

(U) Schedule Profile:

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Beyond Silicon MPT-08	0.000	73.868	94.999	84.700	66.173	43.194	39.453	Continuing	Continuing

(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. The programs within this project were initially budgeted in PE 0601101E, Project MS-01 and PE 0602712E, Project MPT-02 in FY 2001.

(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 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

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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) 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 opportunities as well as technical upgradability 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) 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) 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) This project continues the molecular electronics (Moletronics) program initially funded in Basic Research (6.1) to demonstrate 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

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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) The Interconnected Nano-scale Electronics and Substrates (INES) program aims to interconnect and integrate massive numbers of nano-scale switching devices with conventional deeply-scaled microelectronics. This will enable high performance sensor signal and data processing with very low power dissipation. This program will develop the fabrication technology for creating, placing and interconnecting massive numbers of nanoscale switching devices with high performance interfaces to integrated microelectronic substrates.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Beyond Silicon programs in this PE were initially funded under Project MPT-02. ($33.624 Million)
  - Quantum Information Science and Technology.
  - Polymorphous Computing Architectures.
  - Antimonide Based Compound Semiconductors.
  - Integrated Mixed Signal (A/D) and Electronic/Photonic Systems.
- Moletronics was initiated in PE 0601101E, Project MS-01. ($8.337 Million)

(U) FY 2002 Plans:

- Quantum Information Science and Technology (QuIST). ($23.827 Million)
  - Investigate alternative designs and devices for low overhead fault tolerant communication and computation including solid state, quantum bit (qubit) memory and reliable generation of entangled qubits.
  - 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.
  - Explore designs that can be potentially implemented in existing fiber plants and free space, to include high-energy coherent state mechanisms and polarization compensation.

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- Polymorphous Computing Architectures. ($12.058 Million)
  - Characterize and perform functional decomposition of pivotal reactive system algorithms and computing functions.
  - Develop a representative scalable benchmark suite.
  - Develop and evaluate initial polymorphous computing architecture concepts.
  - Develop multi-dimensional reactive computing optimization, verification techniques.
  - Initiate early prototyping of reactive concepts, software services.

- Antimonide Based Compound Semiconductors (ABCS). ($11.368 Million)
  - 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.

- Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD). ($11.239 Million)
  - 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.

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- Moletronics. ($15.376 Million)
  - 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.

(U) FY 2003 Plans:

- Quantum Information Science and Technology (QuIST). ($27.093 Million)
  - Develop models and scalable architectures for quantum communication and computation, including teleporting information over significant distances.
  - Explore challenges for scaling of bit rate-distance product for quantum secure fiber optic and free-space links via the design of repeaters that leverage teleportation and efficient sources.
  - Demonstrate robust single photon sources and detectors.
  - Determine quantum architecture and design solutions for problems such as graph isomorphism, imaging and signal processing.
  - Develop methods for simulating large quantum problems on a smaller quantum computer; applications to domains such as bond-selective chemistry.
  - Investigate the use of quantum information in clock synchronization and metrology.
  - Analyze the security of communication networks based on quantum key distribution.
  - Investigate error correction scalable to thousands of qubits.
  - Demonstrate scalable quantum computation and memory architectures.
  - Demonstrate active and passive control of coherent quantum states.
  - Demonstrate robust solid-state generation of Einstein, Podolsky, Rosen pairs.

- Polymorphous Computing Architectures. ($18.000 Million)
  - 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.

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- Demonstrate and quantify the potential of full up polymorphic computing architecture systems for the DoD and their complementary commercial viability.

- Antimonide Based Compound Semiconductors (ABCS). ($13.000 Million)
  - 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.

- Integrated Mixed Signal (A/D) and Electronic/Photonic Systems (NeoCAD). ($14.000 Million)
  - 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 methodologies for analog and photonic devices.
    -- Synthesis and layout rules for analog and photonic devices.
    -- Hierarchical design libraries.

- Moletronics. ($15.331 Million)
  - Develop hierarchically directed assembly processes to assemble molecular devices, wires and interconnects.
  - Demonstrate efficient defect-search algorithms.
  - Model the scalability of molecular circuit architectures to high counts and high device densities.

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- Interconnected Nano-scale Electronics and Substrates (INES). ($7.575 Million)
  - Develop surface preparation and selective transfer processes for establishing templates on active substrates for direct interfaces with nano-scale devices and circuits.
  - Initiate development of fabrication technology for nano-scale switching devices.
  - Initiate interconnection of devices with high performance interfaces.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Biologically Based Materials and Devices MPT-09	0.000	0.000	78.250	113.231	142.647	153.207	157.812	Continuing	Continuing

(U) Mission Description:

(U) This new 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 PE0601101E, Project BLS-01.

(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.

(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. Approaches for employing solid, free-form computer-aided design techniques to build tissues are also being examined.

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(U) The goal of the Responsive Membrane Devices (REMEDE) program is to engineer bio-mimetic membrane technology for programmable, multifunctional biotransducers. This program will achieve advances over current state-of-the-art biochip technology and will advance synthetic membrane fabrication techniques, bio-related applications of nanotechnology, bio/solid-state interfaces, artificial cellular responses, induced membrane transport of ions and proteins, molecular recognition capabilities, and bio-mimetic signal amplification. A major goal of this program is to demonstrate an on-chip network of engineered membranes that mimic biological cellular response functions to an environmental stimulus.

(U) The Bio-Magnetic Interfacing Concepts (BioMagnetICs) Materials program will enable nanoscale magnetism to be integrated into biology and demonstrated as a new transduction mechanism for the detection and manipulation of single bio-molecules and cells and as an actuation mechanism for initiating and controlling many cellular functions. This program will result in a number of new DoD capabilities including highly discriminatory biosensing in noisy and variable chemical environments and novel diagnostics and therapeutic treatments for personnel.

(U) Program Accomplishments and Plans:

(U) FY 2001 Accomplishments:

- Not Applicable.

(U) FY 2002 Plans:

- Not Applicable.

(U) FY 2003 Plans:

- Bioinspired and Bioderived Materials. ($27.000 Million)
  - Determine the mechanism of motor function, motor performance and efficiency for several types of biomolecular motors.
  - Initiate biomolecular motor device design for several devices with potential DoD utility.
  - Fabricate and demonstrate new actuating materials for biomimetic appendage development.
  - Design, engineer and demonstrate new soft materials (e.g., actuators, adhesives) based on biological systems in Defense applications.
  - Explore biomimetic sensory fusion processing and integrate biomimetic sensors into mobile platforms.

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- Explore the controlled production of materials using biological systems such as engineered biochemical synthetic pathways and cell and tissue bioreactor plants.
- Demonstrate a synthetic bio-optical system using a bio-inspired lens with a variable index of refraction using materials chemistry and hierarchical structure.
- Explore new bioinspired locomotion in robotic systems.
- Examine systems level bio-locomotion for effeciency in power and mobility in rough terrain.
- Investigate materials for biologically-based fuel cells.

- Biochemical Materials. ($29.250 Million)
  - Explore production methods for manufacture of stable materials from organisms that survive environmental extremes.
  - Explore large-scale production methods for engineered cells with stabilized properties.
  - Identify gene and gene related materials that are associated with stress reduction and extended performance.
  - Demonstrate genes or gene products signatures that predict future physiologic status.
  - Understand pathways and explore biomedical technology required to enhance spatial orientation of the warfighter.
  - Develop self care medical technology to enable the warfighter in the battlefield to accelerate wound healing, hemostasis and pain relief to maintain a functional soldier.
  - Develop new tools and basic understanding of mitochondria for reversible enhancement of functional and physiokinetic endurance via nutritional, pharmaceutical and physical means.

- Responsive Membrane Devices (REMEDE). ($10.000 Million)
  - Demonstrate fabrication of on-chip artificial membranes with microfluidic capabilities.
  - Demonstrate controlled transport through membranes.

- Bio-Magnetic Interfacing Concepts (BioMagnetICs). ($12.000 Million)
  - Demonstrate the ability to selectively impart nanoscale magnetic moments to individual biomolecules and cells.
  - Demonstrate the ability to quantifiably identify and detect the low (less than a picogram per milliliter) presence of magnetically tagged molecules, including proteins, antibodies and nucleic acids.
  - Demonstrate the ability to magnetically trigger cellular responses such as apoptosis, protein expression and/or pigment change.

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– Demonstrate the advantages of a nanoscale biomagnetics transduction mechanism for addressing robustness, portability, and ease-of-use issues associated with providing fieldable devices to the DoD for biological and/or chemical detection, medical diagnostics, and therapeutics.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.