RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999

APPROPRIATION/BUDGET ACTIVITY	R-1 ITEM NOMENCLATURE
RDT&E, Defense-wide BA2 Applied Research	Materials and Electronics Technology PE 0602712E, R-1 #18

COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost To Complete	Total Cost
Total Program Element (PE) Cost	213.386	278.286	235.321	219.063	211.285	209.275	224.071	243.594	Continuing	Continuing
Materials Processing Technology MPT-01	123.603	169.416	111.419	126.512	135.523	135.972	141.054	150.895	Continuing	Continuing
Microelectronic Device Technologies MPT-02	60.972	87.801	97.356	71.216	60.594	63.358	73.215	83.056	Continuing	Continuing
Cryogenic Electronics MPT-06	17.549	18.164	26.546	21.335	15.168	9.945	9.802	9.643	Continuing	Continuing
Military Medical/Trauma Care Technology MPT-07	11.262	2.905	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) <u>Mission Description:</u>

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

(U) The Materials Processing Technology project (MPT-0l) concentrates on the development of novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components which will lower the cost, increase the performance, and enable new missions for military platforms and systems. 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 materials. The project also focuses on smart materials, sensors and actuators, functional materials and devices, 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, protective coating materials to eliminate environmental hazards, infrared artificial dielectrics, development of bio-interface materials and methods, energy harvesting

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concepts, and frequency agile materials based on ferrite and ferroelectric oxides. 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 sensor, robotic, etc. applications.

(U) The Microelectronics Device Technologies project (MPT-02) develops advanced electronic and optoelectronic devices, semiconductor process tools and methodologies, materials for optoelectronics and infrared devices. 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. This project includes a significant effort to develop advanced materials and device technology beyond the classical scaling limits of silicon device technology.

(U) In the Cryogenic Electronics project (MPT-06), thin film electromagnetic materials have reached a stage of development where specific applications can be identified 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) Program Change Summary: (*In Millions*)	**FY1998**	**FY 1999**	**FY 2000**	**FY 2001**
Previous President's Budget	231.353	244.408	234.218	250.208
Current Budget	213.386	278.286	235.321	219.063

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(U) **Change Summary Explanation:**

FY 1998	Decrease reflects DD1415 transfers of LSTAT program to Army, Defense Microelectronic Activity to the Defense Logistic Agency, transition of the Advanced Biomedical Technology program and inflation adjustments.
FY 1999	Increase reflects congressional adds for Seamless High Off-Chip Connectivity (SHOCC); laser diode arrays; nanophase magnetic materials; strategic materials manufacturing; and polymer materials programs.
FY2000-01	Changes reflect expansion of efforts in VLSI photonics, silicon RF and integrated fluidic cooling developments offset by transfer of Biowarfare related portions of the Biomimetic Systems program to PE 0602383E.

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COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost to Complete	Total Cost
Materials Processing Technology MPT-01	123.603	169.416	111.419	126.512	135.523	135.972	141.054	150.895	Continuing	Continuing

(U) <u>Mission Description:</u>

(U) The major goals of this project are to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components which 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, ultra lightweight materials, and multi-functional materials for lowering the weight and increasing the performance of aircraft and spacecraft structures. Approaches are also being developed for reducing the risk of using new materials in defense acquisitions. Smart materials, sensors and actuators for the control of the aerodynamic and hydrodynamic behavior of military systems are being developed and demonstrated to increase performance and lower detectability of aircraft, helicopters, and submarines. "Intrinsically smart" materials that provide self-diagnosis and/or self-repair will be developed as well.

(U) A second 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; 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.

(U) The mesoscopic size range ("sugar cube to fist") offers significant advantages in devices for defense. Efforts include mesopumps for battlefield sensors, mesocoolers, and meso air and water purification for the individual soldier. 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 (batteries, antennae, etc.).

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(U) New materials and concepts for increasing the availability of portable power to the soldier are being investigated, as are approaches for deriving power for soldiers and sensors from the environment. Infrared Artificial Dielectrics (IRADs) are a new class of infrared materials having an emissivity that can be fully engineered for different spectral bands. Finally, the unique characteristics of biologically derived functional 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.

(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Structural Materials and Devices. ($ 29.703 Million)
  - Demonstrated low cost titanium and superalloy component fabrication processes.
  - Demonstrated uniformly bonded face sheet attachment on ultra lightweight foamed metal structures.
  - Demonstrated a 5x reduction in prototyping time (print-to-part) for ceramic and metal gas turbine engine components utilizing solid freeform manufacturing.
  - Demonstrated a laser workcell at a beta test site.
  - Established approaches for breakthrough gains in personnel protection performance (e.g., >100 percent improvement from current capabilities for 7.62 mm armor piercing round) through the application of innovative materials, materials processing and phenomenological modeling of multicomponent materials systems.
  - Initiated mesoscale machine demonstrations of interest to the DoD including a miniature air pump and a micro-cooler.
  - Evaluated an Al-Be F-15 rudder spar.
  - Evaluated structurally porous, ultra-lightweight aircraft panels.
  - Completed the fabrication and evaluation of nanostructured, hard carbon coatings with high adhesion, low friction, high hardness and high wear resistance.

- Smart Materials and Actuators. ($ 24.700 Million)
  - Demonstrated a fabrication process for microintegrated smart materials.
  - Demonstrated full size, smart material active helicopter blade structure and acoustic noise suppression structure on a rotor test stand.
  - Evaluated the actuation potential of magneto-elastic and magneto-shape memory transducer materials.

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- Evaluated high performance electroceramic actuator fabrication processes.
- Demonstrated the applicability of a smart shape adaptive wing to vortex destabilization in hydrodynamic applications.
- Designed, built, tested and evaluated high power laminated actuator stacks for smart defense structures utilizing Computer Aided Manufacturing-Laminated Engineering Materials (CAM-LEM) solid freeform fabrication capability.

• Functional Materials and Devices. ($ 48.000 Million)
  - Demonstrated a prototype giant magneto-resistive (GMR) magnetic memory array and spin transistor memory cell array using magnetic multilayers.
  - Developed microstructural models for prediction of GMR thin film properties.
  - Designed and built a very high sensitivity magnetometer.
  - Continued polymer development using advanced lithography techniques for infrared artificial dielectrics (IRADs).
  - Demonstrated electroactive optical flow characteristics of polymers.
  - Initiated effort to reduce loss tangent in ferrites and ferroelectric oxides for frequency agile RF components.
  - Demonstrated a switched circulator and phase shifter using thick film ferrites.
  - Selected model systems for establishing the structure, chemistry, and function of biotic/abiotic interfaces and biological systems which provide the capability to design biological and biohybrid devices of interest to the DoD (e.g., sensors, smart membranes, actuators, etc.).
  - Demonstrated high-density electronic interconnects for Seamless High Off-Chip Connectivity (SHOCC) interposer.

• Energy and Environmental Sciences. ($ 21.200 Million)
  - Developed balance-of-plant and packaging for a direct oxidation fuel cell replacement for military standard batteries.
  - Demonstrated that full scale, intelligent processing of copper-indium diselenide (CIS) solar cells yields both performance and cost (<$1/watt) suitable for use of flexible photovoltaics in military operations.
  - Developed energy harvesting and storage concepts for unattended devices.
  - Demonstrated the utility of advanced erosion/corrosion resistant thin film coatings at a military site.
  - Demonstrated intelligent processing of thermal barrier coatings yielding reliable coatings, which increase turbine engine inlet temperatures by up to 200 degrees F, with a commensurate increase of 10-15% in thrust.
  - Demonstrated effective silicon-based fouling release coatings for military vessels that offer the potential for maintenance free, cost-effective, non-toxic alternatives to existing anti-fouling paints.

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(U) <u>FY 1999 Plans:</u>

- Structural Materials and Devices. ($ 32.500 Million)
  - Fabricate and test materials and materials systems concepts designed to significantly improve personnel protection performance (e.g., >100 percent improvement from current capabilities for 7.62 mm armor piercing round), dramatically increasing protection for the individual soldier.
  - Demonstrate solid freeform fabrication of titanium forging blanks.
  - Demonstrate spray forming of superalloy forging billets.
  - Demonstrate the use of solid freeform fabrication to upgrade distressed turbine vanes in man-rated gas turbine engines with ceramic composite components of high reliability.
  - Demonstrate initial feasibility, fabrication and performance of prototype mesoscale machines and components (e.g., miniature air blower, microcooler, meso pump, water purifier, etc.).
  - Demonstrate capability of sub-scale mesoscale pumping chambers to meet full-scale air blower design requirements.

- Smart Materials and Actuators. ($ 28.516 Million)
  - Demonstrate vortex wake reduction for submarines using smart materials.
  - Evaluate submarine acoustic noise reduction using smart materials pads and tiles.
  - Demonstrate a full-scale shape adaptive fighter inlet.
  - Establish growth conditions for large piezoelectric single crystals from flux using both open and closed crucible techniques.
  - Evaluate the impact of piezoelectric single crystals on Navy low-frequency surveillance sonar, mid-frequency navigation/tactical sonar, and high-frequency weapons guidance sonar.

- Functional Materials and Devices. ($ 62.800 Million)
  - Demonstrate high speed, radiation hardened, medium density, and non-volatile magnetic memory utilizing magnetic multilayers; develop methods for controlling the microstructure of these giant magneto-resistive (GMR) films during growth.
  - Demonstrate very high sensitivity magnetometer and gradiometer for localization of magnetic anomalies.
  - Demonstrate a permanent magnet material with a 50 percent higher strength (energy product).
  - Expand the use of solid freeform fabrication to demonstrate a new process for the fabrication of silicon carbide devices and simple electronic component parts using rapid tool-less deposition processes.

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- Complete polymer development for infrared artificial dielectrics (IRADs).
- Demonstrate the actuation capability of polymeric muscles.
- Demonstrate a loss tangent less than 0.002 in hybrid ferrite/ferroelectric frequency agile filters.
- Demonstrate a voltage-controlled oscillator (VCO) with an octave tuning range and low loss. Demonstrate scale-up capability for single crystal growth utilizing x-ray interference patterns to template crystal growth.
- Demonstrate enhanced biological responses (molecular, cellular and organismal) at modified material interfaces. Identify approaches for the neurological control and behavior of simple biological systems through biomaterial development.
- Demonstrate actuator materials and bioinspired control strategies for biomimetic locomotion systems; develop biomimetic systems that incorporate extremophile strategies for enhanced stability and performance in the environmental extremes required by the DoD.

• Energy and Environmental Sciences. ($ 24.600 Million)
  - Demonstrate a low temperature, packaged direct oxidation fuel cell for soldier applications.
  - Demonstrate alternative energy sources (including thermal energy conversion) for soldier microclimate cooling and for portable battery chargers.
  - Demonstrate energy harvesting concepts from ambient sources for unattended sensor applications.
  - Investigate fate and transport of chemicals in soil as well as chemotaxis schemes for localization of sources.
  - Demonstrate approaches to augment portable power sources by recovering energy from human activity.
  - Complete demonstration and insertion of advanced erosion/corrosion resistant and anti-fouling thin film coatings in military systems.

• Congressionally mandated program for Seamless High Off-Chip Connectivity (SHOCC). ($ 5.000 Million)
  - Demonstrate the SHOCC concept in an advanced signal processor device in which a flip-chip digital signal processor will be bump bonded to an interposer layer.

• Congressionally mandated program for the development of laser diode bar mounting techniques in laser diode arrays. ($ 3.000 Million)

• Congressionally mandated program for the continuation of research at the Advanced Materials Research Institute to demonstrate nanostructured magnetic materials for enhanced density magnetic media. ($ 7.000 Million)

• Congressionally mandated program for Strategic Materials Manufacturing. ($ 2.000 Million)

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- Congressionally mandated program for the continued development of polymer materials and processing. ($ 4.000 Million)

(U) **FY 2000 Plans:**

- Structural Materials and Devices. ($ 20.100 Million)
  - Integrate material concepts and materials systems into ultra-lightweight armor providing 100 percent improvement in personnel protection for the soldier.
  - Develop analytical, experimental, and simulation technologies for predicting the cost, performance, and life of advanced materials, decreasing the risk of and accelerating the time for insertion of new materials in defense acquisitions.
  - Investigate concepts for the use of multifunctional materials in Defense applications (e.g., blast protection, thermal control) based on successes in ultra-lightweight metals and other structural materials programs.
  - Develop approaches for rapid design, optimization and assembly of small structures and devices based on solid freeform and rapid prototyping technologies.

- Mesoscopic Structures and Devices. ($ 7.000 Million)
  - Demonstrate the operation of a mesoscopic pump array with flow rates over 5 liters/min. in one cubic inch.
  - Build and test an individual integrated mesoscopic cooler.
  - Demonstrate a mesoscopic vacuum pump integrated with a mass spectrometer on a chip.
  - Demonstrate the ability to directly write active and passive electronic materials and components at the mesoscale.

- Smart Materials and Actuators. ($ 23.319 Million)
  - Demonstrate improvements in aerodynamic performance through wind tunnel testing of wings with adaptive leading and trailing edge control surfaces.
  - Develop a “smart skin” for the reduction of self-noise and radiated noise in torpedoes.
  - Explore novel actuator schemes for enhancing the performance of soldiers or devices.
  - Demonstrate techniques to grow large (>3 cm) single crystals of relaxor piezoelectrics.
  - Demonstrate the performance of single crystal piezoelectrics in broadband ultrasonic imaging transducers.

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- Functional Materials and Devices. ($ 42.400 Million)
  - Demonstrate very fast (<20 nsec access time), high density, radiation hardened magnetic memory circuits utilizing both giant magneto-resistance (GMR) multilayers and spin dependent tunneling devices; fully understand the micromagnetics of magnetic domain rotation in these devices.
  - Demonstrate very small, low power, high sensitivity magnetic gradiometers for the localization and identification of small ferrous objects.
  - Demonstrate permanent magnet materials with 75 percent higher magnetic strength (energy product) and the ability to preserve magnetic properties to temperatures over 250 C.
  - Demonstrate a loss tangent less than 0.001 in hybrid ferroelectric/ferrite devices.
  - Demonstrate a broadband 360-degree phase shifter with very low loss for antenna feed applications.
  - Demonstrate polymeric actuators that emulate the mechanical response and performance of human muscles.
  - Demonstrate green light-emitting diodes (LED) fabricated from electroactive polymers, with a half-life >5,000 hours; demonstrate blue and red LEDs with >1,000 hours half-life.
  - Select appropriate polymeric materials with electronic characteristics for field-effect transistor (FET) development.
  - Demonstrate growth of AlGaSb-InAs thin films on GaAs substrates using the lateral epitaxial overgrowth technique.
  - Demonstrate lattice mismatched epitaxial growth of dislocation free compound semiconductors using strain-absorbing layers.

- Bioinspired Materials and Devices. ($ 2.400 Million)
  - Explore sensormotory and navigational control schemes for biological systems through microelectronic interfaces.
  - Evaluate chemical, visual, and acoustic cues used by biological systems for controlled locomotion, behavior, and distribution.
  - Evaluate computational neuromechanics and biomechanics of locomotion.

- Advanced Energy Technologies. ($ 16.200 Million)
  - Demonstrate and field test compact portable power systems in soldier applications.
  - Develop high efficiency direct thermal to electric energy conversion.
  - Demonstrate (in the laboratory) power generation from the environment capable of operating unattended ground sensors.
  - Investigate novel concepts for small-scale, near ambient temperature, chemical power generation.

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(U) **FY 2001 Plans:**

- Structural Materials and Devices. ($ 20.200 Million)
  - Demonstrate ultra-lightweight armor with 100 percent improvement over current materials and begin transition of manufacturing/design capabilities to the Army.
  - Demonstrate the use of multifunctional materials to provide an order of magnitude improvement in the capabilities of specific defense systems.
  - Continue the optimization of analytical, experimental, and simulation technologies for predicting the properties of advanced materials.
  - Select specific material(s) of high value to a DoD system for demonstration of accelerated insertion concepts.

- Mesoscopic Structures and Devices. ($ 12.200 Million)
  - Demonstrate mesoscopic compressor operation that can work against 4 times atmosphere pressure.
  - Demonstrate a mesh of fully functional integrated mesoscopic coolers that exhibit a coefficient of performance >4 and have 1/3 the weight of the smallest normal-scale coolers.
  - Demonstrate that direct-write mesoscale active and passive components have functionality equivalent to discrete surface mount components.
  - Demonstrate the ability to direct-write mesoscale passive components (resistors, capacitors), batteries and patch antennas on conformal surfaces.

- Smart Materials and Actuators ($ 25.500 Million)
  - Complete 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.
  - Complete water tunnel test of a subscale submarine propulsor with active control to reduce acoustic radiation levels.
  - Complete flight test for rotorcraft with blades containing integral actuators and flaps for control of noise and vibration.
  - Develop techniques that use the intrinsic response of a material to its operating environment to provide diagnosis of the performance life of the material.
  - Develop “intrinsically smart” materials that monitor their own state of “health” and repair themselves as required.
  - Demonstrate methods to fabricate multilayer actuators made from single crystals of relaxor piezoelectrics.
  - Demonstrate the performance of single crystal piezoelectrics in an advanced Navy sonar transducer.

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- Functional Materials and Devices. ($ 44.712 Million)
  - Demonstrate a prototype, very high density (>64 Mbit), high speed (<10 nsec access time) magnetic memory circuit based on giant magneto-resistance (GMR) or spin-dependent tunneling utilizing very low power and low voltage (<2.5 Volts).
  - Design a prototype slotless integral motor/pump with advanced magnetic materials for improved efficiency and performance.
  - Demonstrate a steerable ferroelectric lens for phased array radar.
  - Demonstrate a conformal, frequency agile antenna that is 100x smaller than conventional technology.
  - Demonstrate electronic mobility of $>10^{-4}$ cm^2/Vs in electroactive polymeric materials.
  - Demonstrate advantages of polymer based actuators in specific Defense applications (e.g., robotics, sonar).
  - Demonstrate the use of electroactive polymers as thin film spatial filters for quasi-real-time multispectral image analysis for enhancing target detectability.
  - Fabricate a preamplifier for a millimeter wave radar front end with a 4-dB improvement in sensitivity using lateral epitaxial overgrowth fabrication capabilities.
  - Demonstrate the use of twist bonded substrates for integration of an infrared focal plane with integrated read-out electronics.

- Bioinspired Materials and Devices. ($ 7.800 Million)
  - Identify candidates for advanced sensor systems that incorporate biologically inspired concepts including self-calibration, self-healing, variable temperature operation, functionally responsiveness, and mobility.
  - Construct prototype microelectronic interfaces for control of biological systems.
  - Demonstrate millimeter to centimer scale actuators that emulate the locomotion of biological systems.

- Advanced Energy Technologies. ($ 16.100 Million)
  - Demonstrate energy harvesting from the environment for unattended sensor and soldier applications.
  - Demonstrate (in the laboratory) high efficiency direct thermal to electric energy conversion operating on a hydrocarbon fuel.
  - Develop specific approaches for small, chemical power generation that operates at near ambient temperatures.
  - Investigate novel ultra-high energy density power source concepts.

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

- Not Applicable.

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(U) <u>Schedule Profile:</u>

- Not Applicable.

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COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost to Complete	Total Cost
Microelectronic Device Technologies MPT-02	60.972	87.801	97.356	71.216	60.594	63.358	73.215	83.056	Continuing	Continuing

(U) Mission Description:

(U) This project develops advanced electronic and optoelectronic devices, semiconductor process tools and methodologies, materials for Optoelectronics, and infrared devices. Areas of emphasis include high performance analog-to-digital (A/D) converters, military optical processors, novel integrated optoelectronic devices and components, high temperature electronic devices, and high power electronics. This microelectronics development project develops and demonstrates advanced microelectronics technology for DoD critical needs including digital radar receivers and acoustic-electronic components. Technologies developed in this project are performance driven and exceed commercial capabilities. This project includes a significant effort to develop advanced material and device technology beyond the classical scaling limits of silicon device technology.

(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Advanced Microelectronics - Chose candidate interconnect/stacking strategies. ($ 2.400 Million)
- Developed SiC materials for High Power Electronic Power Switching Devices in the 250°- 350°C range demonstrating 11/2 inch diameter wafers with less than one micropipe defects per centimeter squared. ($ 1.700 Million)
- Evaluated thermal management strategies for megawatt-class power switch; evaluated approaches for controlling high-power switch with solid-state electronics (monolithic vs. hybrid); demonstrated 1000-V-class SiC switch. ($ 4.600 Million)
- Explored photonic approaches in the throughput of analog-to-digital (A/D) converters. ($ 3.000 Million)

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- Digital Receiver Processor - Continued efforts to develop advanced digital-based processor components based on high-speed semiconductor technologies, such as heterojunction bipolar transistors. ($ 12.000 Million)

- Sonoelectronics - Initiated development of highly effective sonoelectronic actuators and transducers that can be integrated directly with silicon Very Large Scale Integrated (VLSI) circuits. ($ 7.300 Million)

- VLSI Photonics - Demonstrated feasibility of integration of small arrays (4x4) vertical cavity surface emitting lasers with detectors, and identified degradation mechanism for polymer/small molecule lasers and demonstrated photopumped lasing. ($ 11.100 Million)

- Low Power Electronics - Developed circuits and circuits level design tools to reduce power dissipation for variety of circuits and assist in circuits level tradeoffs. ($ 0.900 Million)

- 3-D Microelectronics - Developed and demonstrated key technologies behind a packaging concept that used a stacked MCM approach to reduce interconnect length and increase physical connectivity between layers of electronics. ($ 4.600 Million)

- Mixed-Mode Electronics - Initiated mixed-mode electronics multitechnology insertion (MIME). ($ 7.000 Million)

- Nanofabrication - Investigated areas of nanofabrication of electronic devices and extreme ultraviolet (EUV) lithography to be used in the next decade for the fabrication of semiconductor devices, such as nanoelectronics and micromechanical structures. ($ 5.600 Million)

- RF Photonics - Completed feasibility demonstration of Radio Frequency Photonics. ($ 0.772 Million)

(U) **FY 1999 Plans:**

- Advanced Microelectronics - Characterize candidate 25-nm transistors $(150nm)^2$ total area and establish process sequence for chip for proof-of-principle demonstration. ($ 8.000 Million)

- Digital Radar Receiver Processor - Develop advanced digital processor components. ($ 11.000 Million)

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- High Power Electronics - Continue development of SiC materials for High Power Electronic Switching Devices increasing water diameter and lowering defect density. Explore new concepts for integration of multiple materials on silicon chips. ($ 4.000 Million)
- Demonstrate high current density (>100 A/cm^2) 1000-V-class SiC high power switch; demonstrate high-temperature (>250 C) operation of a 1000-V-class switch. ($ 7.000 Million)
- VLSI Photonics - Demonstrate integrated 8x8 VLSI photonics chip (laser, detector and electronics) and optoelectronic modeling tools compatible with electronic CAD tools and demonstrate the feasibility of using molecular self-assembly techniques to position optoelectronic devices with high precision on silicon circuits. ($ 20.000 Million)
- Sonoelectronics - Carry out full sonoelectronic integration, combining surface micromachined transducer arrays, low-noise Complementary Metal Oxide Semiconductor (CMOS) electronic readout, acoustic lens and packaging technology, and low-power display technology to fabricate high resolution underwater imager. ($ 8.000 Million)
- HERETIC - Demonstrate heterostructure integrated thermoelectric (TE) or thermionic devices having the same heat-removal capacity as the best commercial off-the-shelf (COTS) TE coolers; fabricate micro-jets, micro-nozzles or micro-thermionic emitters capable of monolithic integration with Si circuits. ($ 5.000 Million)
- Explore concepts in new device technology for 3-D imaging of targets and lightweight electronically steered lasers. ($ 3.301 Million)
- Initiate silicon Reconfigurable Aperture (RECAP) program. Demonstrate microswitches with very low insertion loss, high isolation, and low actuation voltage. Develop fabrication processes for embedded RF microcomponents on large area substrates. ($ 9.000 Million)
- 3-D Microelectronics - 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. ($ 5.500 Million)
- MEMS Deep Etching – Initiate MEMS Deep Etching project. ($ 7.000 Million)

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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

(U) **FY 2000 Plans:**

- (RECAP) - Demonstrate capability to produce large arrays of microswitches. Begin development of integration technologies for switch layers with signal distribution layers. ($ 17.648 Million)

- Digital Receiver Technology Program - Demonstrate a very high performance analog-to-digital (A/D) converter with 14 effective bits, 60 MHz instantaneous bandwidth, and >86 dB spurious free dynamic range (SFDR) in FY00 with potential for multiple military applications. ($ 3.956 Million)

- High-powered Solid State Electronics - Demonstrate high-current density (>100 A/cm^2) 2500-V class switch from SiC; demonstrate 2500-V rectifier diode from GaN. ($ 4.934 Million)

- Sonoelectronics - Complete sonoelectronic camera prototype fabrication, and carry out laboratory characterization and test-tank demonstration. Carry out sonoelectronic integration for air-couple arrays including acoustic matching and electronic read-out technologies. ($ 9.705 Million)

- HERETIC - Complete integration of HIT device arrays with bias and control circuitry on GaAs substrates; complete integration of micro-jet, micro-nozzle or micro-thermionic arrays with bias and control circuitry over Si substrates. ($ 10.780 Million)

- Advanced Microelectronics (AME) - Demonstrate circuit and modeling of a full-scale system (e.g. image processing system) featuring terascaled-compatible devices and associate technology far beyond the existing industry roadmap. ($ 10.786 Million)

- VLSI Photonics - Develop VLSI heterogeneous integration technology and integrate micro-opto-mechanical components with VLSI chips; develop system-level CAD tools. ($ 19.560 Million)

- Heterogeneous Materials Integration on Silicon – Initiate an integration program that develops a tool kit of materials and processes for integration of multiple materials onto a single silicon substrate. ($ 10.987 Million)

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- Photonic Wavelength and Spatial Signal Processing (Photonic WASSP) – Initiate program to begin a major development in photonics, using both wavelengths – wavelength optics – as well as spatial attributes of light – bulk optics. ($ 9.000 Million)

(U) <u>FY 2001 Plans:</u>

- (RECAP) - Develop electronic ground plane technology that provides minimal phase shift and high reflectivity. Demonstrate integration processes for all layers and begin development of combined control function for electronic RF aperture. ($ 19.000 Million)

- Sonoelectronics - Integrate advanced transducer and acoustic-lens technologies into prototype camera. Demonstrate lab-proven imager in very-shallow-water (VSW) field setting. Carry out laboratory demonstration of an air-coupled array as an electronically steered microphone array. ($ 6.000 Million)

- HERETIC - Demonstrate HIT devices on GaAs having twice the specific heat-removal capacity as the best COTS TE coolers; demonstrate micro-jets, micro-nozzles, or micro-thermionic emitters on Si having 5 times the heat-removal capacity as the best convective air or liquid cooling systems. ($ 10.000 Million)

- VLSI Photonics - Demonstrate SAR processor using VLSI Photonics technologies; showcase reconfigurable cross-connect switching. Demonstrate rapid parallel access to memory using optical interconnection. ($ 12.216 Million)

- Digital Receiver Technology - Develop 16 Effective bit, 100 MHz bandwidth A/D converter. ($ 4.000 Million)

- Photonic WASSP – Continue component development, integration, algorithms, architectures and sub-system functionality demonstrations. ($ 11.000 Million)

- Heterogeneous Material Integration – Continue integration of new material and processes into a single silicon substrate that will drive system performance. Demonstrate logic circuits and power amplifiers on silicon. ($ 9.000 Million)

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(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-06

COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost to Complete	Total Cost
Cryogenic Electronics MPT-06	17.549	18.164	26.546	21.335	15.168	9.945	9.802	9.643	Continuing	Continuing

(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 upgraded ship-defense radar (SPQ-9B) with 100X greater detectability of missiles in littoral clutter 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 1998 Accomplishments:

- Cryogenics Technologies. ($ 13.612 Million)
  - Demonstrated a fully functional Cryo-Radar, with 103 dB dynamic range, 15 dB greater than present performance, showing capability to detect targets over that range and an ability to address the defense of surface ships to attacking missiles.
  - Demonstrated, in flight test, a multi-band receiver for the Joint Airborne SIGINT (Signals Intelligence) Avionics Family (JASAF) configuration.
  - Demonstrated the ability to detect low-level unintended radiation at ranges exceeding 50 km.
  - Demonstrated an improved analog to digital (A/D) converter employing cryogenic components.

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- Demonstrated a low-cost (less than $2,500), highly reliable (greater than 30,000 hr) Sterling cycle cryocooler that delivers 5 watts at 80K with less than 200 watts of total power.

• Thermoelectric Materials and Devices. ($ 3.937 Million)
- Demonstrated a thermoelectric cooler that provides a reduction in temperature greater than 50°C in a single stage.

(U) <u>FY 1999 Plans:</u>

• Cryogenics Technologies. ($ 8.396 Million)
- Insert cryogenic packages in communication transceivers that mitigate electromagnetic interference effects.
- Demonstrate SIGINT (Signals Intelligence) applications in aircraft and on the ground.

• Multitechnology Integration in Mixed-Mode Electronics (MIME). ($ 5.000 Million)
- Demonstrate a tunable bandpass filter in the 800-900 MHz range, using a combination of high-temperature superconductivity and micro-electro-mechanical technologies, with Q>5,000 and frequency shift >5%.

• Thermoelectric Materials and Devices. ($ 4.768 Million)
- Demonstrate thermoelectric coolers that can achieve 100°C cooling in three stages or less as compared to the current seven stages.
- Demonstrate potential benefit of efficient power generation from thermoelectric devices operating at high temperature (>500°C).

(U) <u>FY 2000 Plans:</u>

• Cryogenics Technologies. ($ 21.446 Million)
- Develop devices and components, based upon superconducting and other electromagnetic materials that in a cryogenic environment would provide a 5-10X-range improvement over conventional means for detection of low-level signals.
- Complete adaptation of cryocoolers in microelectronics packages for communications transceivers.
- Expand efforts in mixed-mode electronics technology development to include tunable high temperature superconducting filters that preserve high-Q, with 10% tunability.

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- Thermoelectric Materials and Devices. ($ 5.100 Million)
  - Demonstrate thermoelectric coolers that can achieve 100°C cooling in two stages or less.
  - Demonstrate a thermoelectric converter with a factor of two improvements in power generation per unit size.

(U) **FY 2001 Plans:**

- Cryogenics Technologies. ($ 19.220 Million)
  - Fabricate 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.
  - Design a complete cryogenic receiver module, incorporating tunable high temperature superconducting (HTS) antenna/pre-selector and digital microelectronics (with HTS embedded passives), displaying unsurpassed sensitivity and interference rejection.

- Thermoelectric Materials and Devices. ($ 2.115 Million)
  - Demonstrate an all solid state cooler (or thermal converter) that is competitive with conventional phase change systems.

(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-07				
COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost to Complete	Total Cost
Military Medical/Trauma Care Technology MPT-07	11.262	2.905	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) The DARPA Combat Casualty Care program has two major segments: (1) Advanced Biomedical Technology (ABT) and (2) Ultrasonic Diagnostic Imaging. The ABT segment exploits DARPA's unique leadership role in the electronics and information sciences to project advanced medical care into the far-forward battlefield area to effect early, successful clinical intervention. This thrust finished in FY98. DARPA worked with the US Army Medical and Material Command to develop lightweight personnel status monitors (PSMs) permitting casualty identification and localization. Additional sensor capabilities were developed through a "smart tee-shirt," called the sensate liner, which is a fabric woven with fiberoptic, piezoelectric, and other fibers with additional microsensors to provide an entire suite of sensors for vital signs and physiologic monitoring. The Life Support for Trauma and Transport (LSTAT) is a portable Intensive Care Unit, which has the capability of monitoring the soldier and sending information to physicians in the rear echelon hospitals during evacuation from the battlefield. LSTAT completed development, received FDA approval, and was transitioned to US Army Medical and Materiel Command.

(U) The Ultrasonic Diagnostic Imaging segment is developing high-fidelity diagnostic imaging primarily for the far-forward battlefield environment. The emphasis of this effort is on enhancing and miniaturizing biomedical applications of ultrasound. For example, in conventional ultrasound imaging, the medium (i.e., human tissue) is inhomogeneous and scatters the signal, which blurs the image. The processes for developing high-resolution imaging will build upon the emerging technology of adaptive acoustics, the displays of which are intuitive and easily interpreted by the combat medic and physician.

(U) This work does not duplicate any efforts of the Military Services or the National Institutes of Health. A Memorandum of Agreement exists between the Army Medical Department and DARPA.

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(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Advanced Biomedical Technology. ($ 6.045 Million)
  - Completed sensor development for Personnel Status Monitor system and transitioned to the Army.
  - Completed microminiaturized oxygen saturation sensor.
  - Developed and integrated the sensate liner's suite of microsensors.

- 3-D Ultrasound. ($ 5.217 Million)
  - Continued development, test and evaluation of 2-D array ultrasound transducer for portable applications.
  - Continued digital signal processing for high-resolution, high signal-to-noise ultrasound image.

(U) FY 1999 Plans:

- 3-D Ultrasound Technologies. ($ 2.905 Million)
  - Complete ultrasound enhancements for scattering, deaberration, and beam forming; demonstrate resulting system; and transition to the Services.

(U) FY 2000 Plans:

- Not Applicable.

(U) FY 2001 Plans:

- Not Applicable.

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

- Not Applicable.

(U) **Schedule Profile:**

- Not Applicable.