RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE June 2001
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, R-1 #44

COST *(In Millions)*	FY 2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	Cost To Complete	Total Cost
Total Program Element (PE) Cost	245.187	219.467	177.264	159.867	166.400	179.900	168.900	179.900	Continuing	Continuing
Uncooled Integrated Sensors MT-03	15.599	16.798	6.930	7.000	0.000	0.000	0.000	0.000	0.000	N/A
Electronic Module Technology MT-04	51.429	39.965	33.772	31.067	35.075	46.775	46.815	46.775	Continuing	Continuing
Tactical Information Systems MT-05	22.488	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Centers of Excellence MT-07	5.334	5.213	4.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Manufacturing Technology Applications MT-08	14.580	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A
Advanced Lithography MT-10	43.969	55.747	25.013	25.000	25.000	25.000	0.000	0.000	0.000	N/A
MEMS and Integrated Micro-systems Technology MT-12	70.946	48.113	37.590	24.000	24.025	10.825	10.825	10.825	Continuing	Continuing
Mixed Technology Integration MT-15	20.842	53.631	69.959	72.800	82.300	97.300	111.260	122.300	Continuing	Continuing

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

(U) The Advanced Electronics Technology program element is budgeted in the Advanced Technology Development Budget Activity because it seeks to design and demonstrate state-of-the-art manufacturing and process technologies for the production of various electronics and microelectronic devices, sensor systems, actuators and gear drives that have military applications and potential commercial utility. Introduction of

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advanced product design capability and flexible, scalable manufacturing techniques will enable the commercial sector to rapidly and cost-effectively satisfy military requirements and enhance the U.S. industrial base.

(U) The Uncooled Integrated Sensors project addresses a long-standing Defense requirement for uncooled infrared sensor arrays for major weapons systems that cannot accommodate costly cryogenic cooling packages.

(U) The Electronic Module Technology project is a broad initiative to decrease the cost and increase the performance of weapon systems through the insertion of electronic modules. Electronic module technology addresses the design and fabrication of various types of digital, analog and mixed signal modules consisting of electronic, electro-optical and micro-mechanical components. Included in this project is the Photonic Wideband Semiconductor Technology and the Superconducting Hybrid Power Electronics (SuperHyPE) initiatives.

(U) Advanced Lithography technology has enabled the dramatic growth of integrated circuit capability. Advances have led to improvements in electronic and computing systems performance in terms of speed, power, weight and reliability. Further improvements require microcircuits with smaller features to meet the operational seed, power, weight and volume constraints.

(U) The Microelectromechanical Systems (MEMS) and Integrated Microsystems Technology project is a broad and cross-disciplinary initiative to develop an enabling technology that merges computation with sensing and actuation to realize new systems for both perceiving and controlling weapons systems, processes and battlefield environments. Using fabrication processes and materials similar to those that are used to make microelectronic devices, MEMS conveys the advantages of miniaturization, multiple components and integrated microelectronics to the design and construction of integrated electromechanical systems. The microfluidic molecular systems program will address issues centered around the development of automated microsystems that integrate biochemical fluid handling capability along with electronics, opto-electronics and chip-based reaction and detection modules to perform tailored analysis sequences for monitoring of environmental conditions, health hazards and physiological states.

(U) The goal of the Mixed Technology Integration project is to revolutionize the integration of mixed technologies at the micrometer/nanometer scale. This will produce low-cost, lightweight, low-power 3-D microsystems that improve battlefield awareness and the operational performance of military platforms. This project will leverage industrial manufacturing infrastructure to produce mixed-technology microsystems that will revolutionize the way warfighters see, hear, taste, smell, touch and control environments. Also included in this project is the Anti-Tamper initiative which is to protect selected critical technologies in U.S. weapons systems.

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(U) The Centers of Excellence (MT-07) project finances demonstration, training and deployment of advanced manufacturing technology at Marshall University and the Defense Techlink Rural Technology program. This effort will complete during FY 2002.

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

	FY2000	FY 2001	FY 2002
Previous President's Budget	252.388	191.800	188.264
Current Budget	245.187	219.467	177.264

(U) Change Summary Explanation:

FY 2000	Decrease reflects below threshold reprogramming, minor program repricings, and SBIR reprogramming.
FY 2001	Increase reflects congressional adds for Laser Point Source Stepper, Laser Plasma X-Ray Lithography, Defense Techlink, Center for Advanced Microstructures, MEMS for Deep Silicon Etching, Advanced Lithography, and the Navy Center of Excellence partially offset by the Section 8086 reduction and the government-wide rescission.
FY 2002	Decrease reflects the net result of the phase down of the Advanced Lithography project in preparation for technology transition partially offset by the expansion of the Biofluidics program in the Mixed Technology Integration project and the increase for the digital control program.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-03

COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Uncooled Integrated Sensors MT-03	15.599	16.798	6.930	7.000	0.000	0.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) The Uncooled Integrated Sensors project addresses the technology necessary to produce affordable, infrared sensor arrays essential to major weapon systems. The focal plane array consists of a two-dimensional detector array sensitive in a broad spectral range, integrated with unique signal processing to enhance performance and provide more efficient utilization of the information. The critical elements of the technology addressed in this program include the infrared material, detector array fabrication, read-out electronics, cryogenic packaging and testing, and module assembly. Processing and fabrication techniques focus on the production of affordable arrays, at low volume, in the configurations required by weapon systems. Performance enhancements in uncooled infrared and near-infrared sensors are also being addressed to provide an integrated, broadband two-dimensional sensor array without the cryogenic package usually associated with infrared sensors. Thermal Imaging Devices will develop new imaging at the theoretical limit, (five to fifty times increase over current uncooled devices), achieving high performance in extremely small, low power configurations and demonstrating technology to open new applications for imaging devices.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Uncooled Imaging Sensors & Devices. ($ 7.599 Million)
  - Demonstrated 480x640-uncooled arrays with < .05 milli-Kelvin, 1 mil pixel.
  - Transferred 480x640 uncooled infrared sensor to Army missile seeker program.
  - Conducted field evaluation of high sensitivity uncooled infrared sensor with low light sensor for ground operations.

- Thermal Imaging Devices. ($ 8.000 Million)
  - Demonstrated non-contact read-out devices and characterized sensitivity/noise sources.
  - Demonstrated non-contact imaging array with thermal sensitivity of 100 milli-Kelvin.

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(U) FY 2001 Plans:

- Uncooled Imaging Sensors & Devices. ($ 12.826 Million)
  - Demonstrate 100 gram imaging sensor with performance acceptable for micro-air-vehicles.
  - Optimize read-out structure to read signals with short (approximately 1 msec.) integration time.
  - Conduct three-D thermal imaging phenomenological experiments and studies.

- Electro-Optics IR Technology Center. ($ 3.972 Million)
  - Develop the next generation infrared and night vision sensor technology, consisting of large arrays of multi-spectral detectors, with integral signal processing, addressing systems' needs for threat warning and target acquisition.
  - Incorporate innovative detector and signal processor designs to maximize operating temperature, while maintaining the target discrimination capability at the maximum system range.

(U) FY 2002 Plans:

- Uncooled Imaging Sensors & Devices. ($ 6.930 Million)
  - Incorporate high responsitivity materials into detector structure.
  - Integrate materials and microstructure into imaging device.

(U) Other Program Funding Summary Cost:

- Not Applicable

(U) Schedule Profile:

Plan	Milestones
Aug 01	Demonstrate 100 gram imaging sensor with performance acceptable for micro-air-vehicles.

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Dec 01	Demonstrate 50-gram sensor with sensitivity of 20 milli-Kelvin.
Jan 02	Incorporate high responsitivity materials into detector structure.
Mar 02	Integrate materials and microstructure into imaging device.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development	R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-04

COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Electronic Module Technology MT-04	51.429	39.965	33.772	31.067	35.075	46.775	46.815	46.775	Continuing	Continuing

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

(U) The Electronic Module Technology Project is a broad initiative to substantially decrease the cost and increase the performance of weapon systems through the timely insertion of state-of-the-art electronic modules. Electronic module technology addresses the design and fabrication of various types of digital, analog and mixed signal modules consisting of electronic, electro-optical and micro-mechanical components. It includes traditional approaches such as printed circuit boards, and emerging technologies such as high density Multichip Modules.

(U) The project has three major objectives: (l) shorten the overall design, manufacture, test and insertion cycle for advanced electronic subsystems; (2) advance the state-of-the-art in electronic interconnection and physical packaging technology to allow circuits to operate close to their intrinsic maximum speed with less overhead in terms of volume, weight and cost; and (3) provide a robust manufacturing infrastructure for electronic modules.

(U) The project has the following major elements: Photonic Analog/Digital (A/D) Conversion; Distributed Robotics; Design Support for Mixed Technology Integration (Composite CAD), the Molecular-level Large-area Printing (MLP), the Wide Band Gap RF Semiconductor program and the Superconducting Hybrid Power Electronics (SuperHyPE) program. Photonic Analog/Digital (A/D) conversion will utilize breakthrough photonic developments to substantially increase the speed that analog signals are converted into digital data streams for data reduction and processing. Distributed Robotics is an effort to integrate developments in Microelectromechanical Systems (MEMS), power sources, communications and advanced microelectronics to design, construct and field multiple, high-performance, mobile, autonomous systems. Composite CAD seeks to develop the design tools (concept exploration, analysis, optimization and verification) to allow thousands of analog, digital, optical, MEMS and microfluidic devices to be integrated into "systems-on-a-chip" and other highly integrated mixed technology systems. The MLP program is exploring approaches to 'print' MEMS devices on large surfaces.

(U) The Photonic Wide Band Gap RF Semiconductor Technology program will develop wide band gap materials for optical emission in the ultraviolet for bio sensing, and covert communications applications. This program will develop high conductivity *p*-type (positive charge carrier)

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material, and highly efficiently active region material suitable for ultraviolet emission and exploit these results to enable the development of heterojunction bipolar transistors (HBT).

(U) The Superconducting Hybrid Power Electronics (SuperHyPE) program will demonstrate a new paradigm in power electronics for the "all electric" vehicles of the future. Combining superconductivity, cryogenics and power electronics for self contained platforms will provide a) improved controllability via rapid response and ease of interface with digital control systems, b) significantly reduced maintenance, c) reduced complexity through reduced number of energy transformations and reduced support requirements, d) increased efficiency through less energy conversion and improved primary power sources, e) new applications such as pulsed energy systems, directed energy weapons, rail guns, and f) fully automatic systems to reduce personnel needs. These hybrid systems offer significant increases in specific power density, which provide weight, and volume savings that scale with the overall size of the system. This can easily translate to an order or magnitude saving for a moderate size system (5000 HP) and significantly more for large systems (>20,000 HP).

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Photonic A/D. ($ 14.787 Million)
  - Evaluated alternative photonic clock, optical sampler and quantizer module designs for photonic A/D converters operating in the 10-100 Giga-sample-per-second range.
  - Identified high impact applications for this technology.

- Distributed Robotics. ($ 12.378 Million)
  - Demonstrated feasibility of a variety of multiple robots (<5cm) operating in specific military environments and their ability to adapt to varying environments and missions.
  - Demonstrated probability of mission success improved by distributed functionality.

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- Composite CAD. ($ 9.945 Million)
  - Completed the development of systems software design and simulation capabilities for mixed technology micro-systems, including MEMS-enabled designs and micro fluidic (Micro-Flumes) designs. The ultimate goal of the complete systems design capability is to enable mixed technology systems-on-a-chip.
  - Provided mixed technology design libraries, models and test structure data to improve design quality, development time and ability to reuse designs.

- Molecular-level Large-area Printing (MLP). ($ 14.319 Million)
  - Concentrated on the development and choice of non-conventional large-area, MLP techniques for a demonstration system.
  - Established overlay capabilities for MLP.

(U) **FY 2001 Plans:**

- Photonic A/D. ($ 15.459 Million)
  - Complete initial photonic analog/digital (A/D) converter evaluation and finalize design for demonstration module.
  - Demonstrate key photonic technologies.

- Distributed Robotics. ($ 12.678 Million)
  - Demonstrate multiple robots with overall functionality and probability of mission success improved by integration of optimized control strategies.

- Molecular-level Large-area Printing (MLP). ($ 11.828 Million)
  - Demonstrate and characterize 10,000 x 100 pixel density array on a spherical surface.

(U) **FY 2002 Plans:**

- Photonic A/D. ($ 8.557 Million)
  - Complete photonic analog/digital converter technology development.

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- Integrate photonic clock and sampler modules with electronic quantizers.
- Complete analog/digital converters with at least 10 gigasamples/sec.
- Demonstrate high linearity and dynamic range.

• Distributed Robotics. ($ 4.749 Million)
  - Complete current contracts on micro robot developments.
  - Deliver prototype hardware and final reports.
  - Demonstrate with operational military users.

• Photonics Wide Band Gap RF Semiconductor Technology. ($ 10.000 Million)
  - Demonstrate *p*-type (positive charge carrier) doping in high aluminum concentration nitride materials at concentrations sufficient for minority carrier injection devices.

• Superconducting Hybrid Power Electronics (SuperHyPE). ($ 10.466 Million)
  - Identify target power modules and platform for maximum benefit of hybrid approach.
  - Initiate design for integrated hybrid power module.

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

• Not Applicable.

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(U) Schedule Profile:

Plan	Milestones
Jul 01	Demonstrate and characterize 10,000-x 100-pixel density array on spherical surface.
Aug 01	Demonstrate multiple robots with overall functionality and probability of mission success improved by integration of optimized control strategies.
Jul 02	Develop high power high temperature devices.
Sep 02	Demonstrate high temperature operation of integrated power switches.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Centers of Excellence MT-07	5.334	5.213	4.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A

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

(U) This project provides funding for the Robert C. Byrd Institute for Advanced Flexible Manufacturing at Marshall University. The Byrd Institute provides both a teaching factory and initiatives to local area industries to utilize computer-integrated manufacturing technologies and managerial techniques to improve manufacturing productivity and competitiveness. Training includes technologies to significantly reduce unit production and life cycle costs and to improve product quality. This project also includes funding for the Defense Te chlink Rural Technology Transfer Project.

(U) <u>Program Accomplishments and Plans:</u>

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

- Advanced Flexible Manufacturing. ($ 3.834 Million)
  - Expanded the Institute for Advanced Flexible Manufacturing's web-based electronics supply chain support to include 150 small manufacturers who now have access to Defense on-line procurement activities.

- Defense Techlink Rural Technology Transfer Project. ($ 1.500 Million)
  - Provided funding for the Defense Techlink Rural Technology Transfer Project.

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

- Advanced Flexible Manufacturing. ($ 3.972 Million)
  - Continue to expand the web based electronics supply chain and increase the number of manufacturers who have access to, and qualify for, Defense acquisitions.

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- Defense Techlink Rural Technology Transfer Project. ($ 1.241 Million)
  - Provide funding for the Defense Techlink Rural Technology Transfer Project.

(U) FY 2002 Plans:

- Advanced Flexible Manufacturing. ($ 4.000 Million)
  - Complete assessment of the Institute for Advanced Flexible Manufacturing's performance and transition from DoD to state/private support.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

Plan	Milestones
Sep 01	Complete Defense Techlink Rural Technology Transfer Project.
Sep 02	Complete assessment and transition of the Institute for Advanced Flexible Manufacturing from DoD to state/private support.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Advanced Lithography MT-10	43.969	55.747	25.013	25.000	25.000	25.000	0.000	0.000	0.000	N/A

(U) Mission Description:

(U) Microelectronics is a key to improved weapon system performance. Lithography technology has enabled the dramatic growth in microelectronics capability over the past three decades. The improved capabilities in semiconductor technology contribute to significant system gains in speed, reliability, cost, power consumption and weight. Advanced microelectronics technology is essential for computing and signal processing in virtually all military systems including command, control, communications and intelligence; electronic warfare; and beam forming for radar and sonar. Further improvements in areas such as target recognition, autonomous guided missiles and digital battlefield applications require microcircuits with smaller features to meet the operational speed, power, weight and volume constraints of these systems.

(U) Current microelectronics fabrication utilizes feature sizes of 0.18 microns. The Advanced Lithography program emphasizes longer-term research with expected high payoff in the fabrication of semiconductor devices with 0.05 or less micron feature sizes. These efforts will develop technology for sub 0.05 micron features.

(U) The goal of the Advanced Lithography program is to reduce technical barriers to the development of advanced lithographic technologies for the fabrication of a broad range of microelectronic devices and structures. Innovative research in pattern generation and transfer, imaging materials, new process and metrology will provide alternatives beyond current evolutionary trends. The program will investigate technologies for the creation of highly complex patterns at sub 0.05 ?m resolution over field areas in excess of 1000 mm^2. Applications with larger geometries will be explored for innovative devices and structures beyond microelectronics, including nanolithography.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- Sub 0.1 Micron Lithographies. ($ 21.969 Million)

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- Developed key tool components, materials and processing to accelerate the availability of emerging lithography technologies beyond 193 nm. Efforts included maskless (electron beam, ion beam) approaches and projection technologies, using optical, electron, x-rays and extreme ultraviolet.

- Support Technologies. ($ 16.000 Million)
  - Developed support technologies, to include mask technology, resists and metrology.
  - Developed innovative optics designs, architectures and new materials, and processing beyond the evolutionary trends in the industry.

- Laser Plasma X-ray Source. ($ 5.000 Million)
  - Continued laser plasma x-ray source technology.

- Point Source Lithography. ($ 1.000 Million)
  - Continued point source lithography development.

(U) **FY 2001 Plans:**

- Sub 0.1 Micron Lithographies. ($ 23.031 Million)
  - Demonstrate key components of maskless wafer writer and key components for lithography of 0.07 micron features.

- Support Technologies. ($ 19.112 Million)
  - Accelerate technology developments in the lithography exposure sources and supporting (cross-cutting) technologies needed for microelectronics fabrication.
  - Develop reduced risks in key areas of components, materials and processing allowing industry to fabricate prototype tools and new high-performance devices for use in advanced military systems and commercial markets.

- Laser Plasma X-Ray Source. ($ 4.965 Million)
  - Continue laser plasma x-ray source technology.

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- Point Source Lithography. ($ 3.674 Million)
  - Continue point source lithography development.

- Advanced Lithography Mask Development. ($ 4.965 Million)
  - Continue lithography mask development.

(U) <u>FY 2002 Plans:</u>

- Sub 0.1 Micron Lithographies. ($ 15.013 Million)
  - Develop key tool components, materials and processing for both maskless and projection approaches for lithography at 0.05 microns and below.
  - Fabricate prototype devices for military applications with features at 0.1 micron.

- Support Technologies. ($ 10.000 Million)
  - Develop mask technology (writing, inspection and repair), resists and metrology for lithography for sub 0.1 micron.
  - Develop resists that will emphasize thinner resists appropriate for emerging exposure sources.

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

- Not Applicable.

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

Plan	Milestones
Aug 02	Demonstrate key components for lithography of 0.07 micron features.
Sep 02	Demonstrate key components for mask writer for sub 0.1 micron features.
Aug 03	Demonstrate prototype tool for fabrication of devices with 0.07 micron features.
Aug 04	Demonstrate key components for fabrication of devices with 0.05 micron features.
Aug 05	Demonstrate prototype tool for fabrication of devices with 0.05 micron features.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development					R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E, Project MT-12					
COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
MEMS and Integrated Micro-systems Technology MT-12	70.946	48.113	37.590	24.000	24.025	10.825	10.825	10.825	Continuing	Continuing

(U) Mission Description:

(U) The Microelectromechanical Systems (MEMS) program is a broad, cross-disciplinary initiative to develop an enabling technology that merges computation and power generation with sensing and actuation to realize a new technology for both perceiving and controlling weapons systems and battlefield environments. Using fabrication processes and materials similar to those that are used to make microelectronic devices, MEMS provides the advantages of miniaturization, multiple components and integrated microelectronics to the design and construction of integrated electromechanical and electro-chemical-mechanical systems. The MEMS program addresses issues ranging from the scaling of devices and physical forces to new organization and control strategies for distributed, high-density arrays of sensor and actuator elements. These issues include microscale power and actuation systems as well as microscale components that survive harsh environments. The microfluidic molecular systems program will develop automated microsystems that integrate biochemical fluid handling capability along with electronics, optoelectronics and chip-based reaction and detection modules to perform tailored analysis sequences to monitor environmental conditions, health hazards and physiological states.

(U) The MEMS program has three principal objectives: the realization of advanced devices and systems concepts; the development and insertion of MEMS into DoD systems; and the creation of support and access technologies to catalyze a MEMS technology infrastructure. These three objectives cut across a number of focus application areas to create revolutionary military capabilities, make high-end functionality affordable to low-end systems and extend the operational performance and lifetimes of existing weapons platforms. The major technical focus areas for the MEMS program are: 1) inertial measurement; 2) fluid sensing and control; 3) electromagnetic and optical beam steering; 4) mass data storage; 5) chemical reactions on chip; 6) electromechanical signal processing; 7) active structural control; 8) analytical instruments; and 9) distributed networks of sensors and actuators.

(U) Compact portable power sources capable of generating power in the range of a few hundred milliwatts to one watt are critical to providing power for untethered sensors and other chip-scale microsystems. This program aims to replace today's technologies relying on primary and rechargeable batteries, which severely limit mission endurance and capabilities, by extending microelectronic machine technology to develop micro-

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power generators based on mechanical actuation and thermal-electric power generation. Operating with traditional fuels, these micropower generators will be capable of generating sustained power in the desired range for use with remote, field-deployed microsensors and microactuators.

(U) Within this project is the development of totally integrated microfluidic chips to enable ubiquitous yet unobtrusive assessment of the warfighter's body fluids. These microchips integrate detection, diagnostics and treatment in one chip-scale system called Bio-Fluidic chips.

(U) Program Accomplishments and Plans:

(U) FY 2000 Accomplishments:

- MEMS Devices and Processes. ($ 18.817 Million)
  - Developed new devices and processes that survive extremely harsh environments and facilitated the integration of micro-mechanical as well as micro-chemical systems into electronic circuits. These new devices include micro power sources, mechanical-microprocessor units, micro actuators, communication components, MEMS aerodynamic pressure sensors on flexible adhesive tape substrate; modular, monolithically integrated MEMS Inertial Measuring Unit (IMU); and MEMS high-temperature sensor and actuator arrays.
  - Demonstrated micro devices that will reduce communication equipment to the size of a credit card; optimized the aerodynamics of an airplane wing for lift and drag, provided intelligence to machine components to allow them to report their condition and state of readiness (e.g., "smart wheel bearings"), and increased the resistance of jamming of GPS used on smart munitions.
  - Integrated power sources with the MEMS devices and expanded the use of MEMS in fluidic applications.

- MEMS System Design and Development Phase II. ($ 16.211 Million)
  - Initiated technology demonstrations relevant to micro airborne sensor/communicator platforms and chemically powered remote sensors, subsystems for Pico Satellites, electromechanical signal processing and nanoelectromechanical systems.

- CAMD. ($ 3.888 Million)
  - Continued micro device manufacturing processes at the Center for Advanced Microstructures and Devices (CAMD).

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- MEMS MicroPower Generation. ($ 23.030 Million)
  - Demonstrated feasibility and practical limits of converting chemical energy into electrical energy on the micro-scale using MEMS technology. The goal is to replace primary and rechargeable batteries with micropower generators that have at least one order of magnitude higher energy density, and thus drastically reducing weight and volume of power sources.
  - Developed high-energy density power generation on micro-scale from fuels.
  - Developed stand alone, remotely distributed MEMS sensor networks.

- Bio-Fluidic Chips (BioFlips). ($ 9.000 Million)
  - Designed microscale fluidics integrated with optical and/or electronic detection to monitor cellular activities of body fluids.
  - Designed chip interface with bio-fluids for continuous sampling and fluids delivery.
  - Developed on-chip reagent storage and reconstitution.

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

- MEMS Micro Power Generation. ($ 19.694 Million)
  - Demonstrate chip-level integration of components for fuel processing, thermal management, energy conversion and exhaust management for micropower generation. Enable stand alone, remotely distributed microsensors with built-in power supply and RF communication in addition to various sensing functions.
  - Develop MEMS free-piston knock engine.
  - Develop an integrated fuel cell and fuel processor for microscale power generation from liquid fuels.
  - Develop integrated chemical fuel microprocessor for power generation in MEMS applications.
  - Develop 3-D monolithically fabricated thermoelectric micro generator.

- CAMD. ($ 2.731 Million)
  - Continue micro device manufacturing process at the Center for Advanced Microstructures and Devices (CAMD).

- Deep Silicon Etching. ($ 7.944 Million)
  - Complete MEMs Deep Etching program in conjunction with the Army Research Laboratory.

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- Bio-Fluidic Chips (BioFlips). ($ 17.744 Million)
  - Develop closed-loop bio-fluidic chips to regulate cellular transduction pathways and precise dosage of chemicals/drugs/ reagents/enzymes.
  - Fabricate and test individual microfluidic chip components and integrated sensors for flow control.
  - Manipulate (pump/valve/sense) bio-fluids in integrable microfluid components.

(U) **FY 2002 Plans:**

- MEMS Micro Power Generation. ($ 19.789 Million)
  - Demonstrate capabilities in fuel processing, energy conversion to electricity, thermal and exhaust management.
  - Demonstrate MEMS micro heat engines utilizing micropower sources.

- Bio-Fluidic Chips (BioFlips). ($ 17.801 Million)
  - Demonstrate optimization of sub-systems and components for integration into prototype systems. Sub-systems include: 1) on-chip sample preparation and processing (on-chip flow/concentration regulators, biosignal amplification, on-chip pressure sources, on chip separation/mixing, reagents storage/reconstitution); 2) sample collection (body fluid extractors, concentrators); and 3) antidote synthesis (genetic and antibodies) subsystems.
  - Identify partners in the DoD and other federal agencies for testing prototype systems.
  - Perform preliminary testing of prototype systems for re-evaluation of sub-system functionality.

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

- Not Applicable.

(U) **Schedule Profile:**

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Plan	Milestones
Sep 01	Demonstrate atomic resolution data storage.
Jul 02	Demonstrate BioFlips optimization of sub-systems and components.
Feb 02	Demonstrate micro heat engines.
Aug 03	Demonstrate electrical power generation.
Aug 03	Test and optimize BioFlips prototype.

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COST *(In Millions)*	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Mixed Technology Integration MT-15	20.842	53.631	69.959	72.800	82.300	97.300	111.260	122.300	Continuing	Continuing

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

(U) The goal of the Mixed-Technology Integration project is to leverage advanced microelectronics manufacturing infrastructure and DARPA component technologies developed in other projects to produce mixed-technology microsystems that will revolutionize the way individuals see, hear, taste, smell, touch and control their environment at-a-distance, a paradigm that addresses many of the present and future needs of the DoD. These 'wristwatch size', low-cost, lightweight and low power microsystems will improve the battlefield awareness and security of the warfighter and the operational performance of military platforms. At the present time, systems are fabricated by assembling a number of mixed-technology components: Microelectromechanical Systems (MEMS), microphotonics, microfluidics and millimeterwave/microwave. Each technology usually requires a different level of integration, occupies a separate silicon chip and requires off-chip wiring, fastening and packaging to form a module. The chip assembly and packaging processes produce a high cost, high power, large volume and lower performance system. This program is focused on the monolithic integration of mixed technologies to form batch-fabricated, mixed technology microsystems 'on-a-single-chip' or an integrated and interconnected 'stack-of-chips'.

(U) Microelectronics incorporates micrometer/nanometer scale integration and is the most highly integrated, low-cost and high-impact technology to date. Microelectronics technology has produced the microcomputer-chip that enabled or supported the revolutions in computers, networking and communication. This program extends the microelectronics paradigm to include the integration of heterogeneous or mixed technologies. This new paradigm will create a new class of 'match-book-size', highly integrated device and microsystem architectures. Examples of component-microsystems include low-power, small-volume, lightweight, microsensors, microrobots and microcommunication systems that will improve and expand the performance of the warfighter, military platforms, munitions and UAVs.

(U) The program includes the integration of mixed materials on generic substrates including glass, polymers and silicon. The program is design and process intensive, using 'standard' processes and developing new semiconductor-like processes and technologies that support the integration of mixed-technologies at the micrometer/nanometer scale. The program includes the development of micrometer/nanometer scale isolation, contacts, interconnects and 'multiple-chip-scale' packaging for electronic, mechanical, fluidic, photonic and rf/mmwave/microwave technologies. For example, a mixed-technology microsystem using integrated microfluidics, MEMS, microphotonics, microelectronics and

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microwave components could provide a highly integrated, portable analytical instrument to monitor the battlefield environment, the physical condition of a warfighter, the identity of warfighters (friend or foe) or the combat readiness of equipment. The ability to integrate mixed technologies onto a single substrate will drive down the size, weight, volume and cost of weapon systems while increasing their performance and reliability.

(U) The 3-Dimensional Imaging Devices program is developing new high speed imaging devices and array technology to rapidly acquire high resolution (less than 6 inches in range) three dimensional images of tactical targets at ranges of 7 to 10 kilometers, thereby increasing identification range of tactical targets, especially from fast moving platforms.

(U) The Steered Agile Laser Beams (STAB) program is developing small, lightweight laser beam scanning technologies for the replacement of large, heavy gimbaled mirror systems. New solid state/micro-component technologies such as optical MEMs, patterned liquid crystals and diffractive micro-optics will be used to build small, ultra-light, rapidly steered laser beam sub-systems.

(U) The Radio Frequency (RF) Lightwave Integrated Circuits (RFLICS) program is demonstrating enhanced performance capabilities of RF systems enabled by integration of lightwave and RF technologies to route, control, and process analog RF signals in the 0.5 – 50 Ghz range.

(U) The Engineered Molecular Flow Devices or BioFluidics program is developing and testing chip scale molecular flow control arrays for sensing contaminants.

(U) The Nano Mechanical Array Signal Processors (NMASP) program will create arrays of precision, nano mechanical structures for radio frequency (RF) signal processing that will greatly reduce the size and power consumption of various communication systems.

(U) The goal of the Chip Scale Wavelength Division Multiplexing (WDM) program is to develop new materials, components and sub-systems for use in wavelength division multiplexing based optical communications, delivering high capacity, mission adaptable networks for use in data intensive military weapons systems.

(U) Digital Control of Analog Circuits will demonstrate analog/RF electronic components with the ability to self-assess and adapt in real time (sub microseconds), by self-tuning its impedance-matched networks, extending the operational performance of analog components to the intrinsic

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semiconductor device limits. This technology will result in a new generation of analog, microwave and millimeter wave components with >150X improvements in power-bandwidth, linearity-efficiency products.

(U) The goal of the Anti-Tamper (AT) initiative is to protect selected critical technologies in U.S. weapons systems that may be developed with or sold to foreign governments or that could possibly fall into enemy hands. Specifically, AT is intended to prevent technology transfer, alteration of system capability, and development of countermeasures due to weapon system co-development, sales, or potential loss on the battlefield. An AT technology base will develop complimentary AT techniques with broad applicability across the range of DoD critical technologies. Areas of AT technology interest include software, digital electronics, materials, and systems operating across the electromagnetic spectrum.

(U) <u>Program Accomplishments and Plans:</u>

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

- 3-D Imaging Devices. ($ 7.109 Million)
  - Initiated program to develop new high speed imaging device technology to rapidly acquire a high-resolution 3-D image of a tactical target at ranges of 7-10 kilometers increasing identification range of tactical targets, especially from fast moving platforms.
  - Developed near infrared materials with point defect density less than 1000/sq cm.
  - Demonstrated 4x4 array of detectors with gain of 30 at 1 GHz.
  - Completed investigation of novel high gain detector concept.

- Steered Agile Laser Beams (STAB). ($ 6.630 Million)
  - Initiated program to develop compact, lightweight, man-portable, electronically steered lasers to replace large, heavy gimbal mounted lasers in lasercom links and smart weapon target designators.
  - Developed small, lightweight laser beam scanner system technologies for replacement of gimbaled mirror systems.
  - Initiated system design and component specifications; selected system design.

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- RF Lightwave Integrated Circuits (RFLICS). ($ 7.103 Million)
  - Initiated program to demonstrate, with heterogeneous integration, lightwave and RF technologies to route, control and process analog RF Signals in the 0.5-50 GHz range.
  - Developed RF-Photonic modules to enable links with better than zero net RF loss from input to output.
  - Developed and demonstrated optically integrated modules capable of performing complex RF functions such as signal channelization or single chip generation of multiple RF signals.

(U) **FY 2001 Plans:**

- 3-D Imaging Devices. ($ 20.980 Million)
  - Complete design of high-speed electronics for sub-nanosecond detection.
  - Initiate experiments in exploiting and adapting emerging technology in nanofabrication to create nano resonators by chemical and physical transfer of materials on nano-scale patterns.
  - Integrate high-speed electronics with 5x5-detector array and integrate into brass board imaging system.
  - Demonstrate laboratory imaging with 5x5 array.
  - Select detector design for 128x128 3-D imaging array.

- Steered Agile Laser Beams (STAB). ($ 17.825 Million)
  - Develop electronically steered laser beam technology for use in covert, anti-jam, high bandwidth battlefield communications - hand held ground-to-ground recon units that are able to transmit images and geo-location data of targets, and for use in target designators for small unit operations in high threat environments.
  - Fabricate beam steering emitters and detectors.

- RF Lightwave Integrated Circuits (RFLICS). ($ 14.826 Million)
  - Focus program on identified key applications for integrated RF-Photonic modules and produce initial prototypes and demonstrate methods for evaluation of their performance.
  - Initiate parallel efforts to develop components for efficient RF links exhibiting better than zero net loss and to demonstrate the advantages of integrated optical-RF modules for RF systems.

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– Down-select among technology options and develop prototype module for demonstration.

(U) **FY 2002 Plans:**

- 3-D Imaging Devices. ($ 11.625 Million)
  - Demonstrate range imaging at the eye-safe wavelength of 1.54 micrometers, with a minimum array size of 64x64. The goal is target identification range of 10 km with single laser pulse imaging.

- Steered Agile Laser Beams (STAB). ($ 14.357 Million)
  - Analyze system concepts that will be used to develop design goals for assembled components.
  - Fabricate individual laser beam steering components (lasers, diffractive optics, micro electro-mechanical (MEMS) sub-assemblies, detectors, filters and integrated circuits).
  - Resolve component interface issues in preparation for breadboard development.

- RF Lightwave Integrated Circuits (RFLICS). ($ 11.977 Million)
  - Determine the quantitative performance requirements of computationally intensive weapons systems tasks such as RF channnelization, local oscillator distribution, antenna beam forming, jammer nulling, and signal synthesis and frequency conversion.
  - Use results of earlier RF photonics single chip development effort to establish goals for RF photonic component fabrication.
  - Integrate recently developed emitters, waveguides, detectors and integrated circuits to produce RF photonic component prototypes.

- Nano Mechanical Array Signal Processor (NMASP). ($ 11.000 Million)
  - Demonstrate fabrication techniques to control surface morphology, geometry, and material properties at the sub-micron scale.
  - Demonstrate temperature stability and electrical tenability of individual nano resonators suitable for UHF communication.
  - Initiate development of nano mechanical array signal processors that will enable ultra miniaturized (wristwatch or hearing aid in size) and ultra low power UHF communicators/GPS receivers.

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- Digital Control of Analog Circuits. ($ 7.000 Million)
  - Demonstrate real-time active self-assessment and monitoring of RF/analog functions using nano-CMOS digital and mixed-signal technologies to achieve stability, signal agility, and multifunctionality.
  - Design processes to fabricate arrays of molecular flow control devices including interconnect microfluidics and electronics.

- Chip Scale Wavelength Division Multiplexing (WDM) for Military Platforms. ($ 6.000 Million)
  - Conduct modeling, simulation and analysis of artificial dielectrics and new materials for ultra-compact Wavelength Division Multiplexing (WDM) components.
  - Conduct experimental efforts in the growth and fabrication of these new materials and determine suitable processing procedures.
  - Plan construction of WDM components.

- Anti-Tamper (AT). ($ 8.000 Million)
  - Facilitate information exchanges throughout the Services, DoD Agencies and Labs and industry to preclude development of duplicative technologies.
  - Develop an interactive AT databank and library.
  - Develop a technology roadmap required to prioritize the overall technological research and development effort.
  - Develop AT technology throughout the Radio/Frequency/Gallium Arsenide and Digital Gallium Arsenide domains.

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

- Not Applicable.

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

<u>Plan</u>	<u>Milestones</u>
3-D Imaging:	
Jun 02	Demonstrate range imaging at eye safe wavelengths.

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STAB:

Aug 01	Fabricate beam steering emitters and detectors.
Jul 02	Fabricate laser beam steering components.
May 03	Complete prototype design studies.

RFLICS:

Aug 01	Demonstrate integrated RFLICS functions such as channelizer with 10 GHz selectivity over 0-50 GHz bandwidth.
Aug 02	Integrate emitters, waveguides and detectors into RF photonic component prototypes.
Sep 03	Complete design and fabrication of RF photonic prototypes.

WDM:

Aug 02	Develop artificial dielectrics suitable for compact WDM modules.
Aug 03	Design, fabricate, and test WDM modules.

NMASP:

Jul 02	Demonstrate electrically controlled tunability suitable for UHF communication.
Aug 03	Demonstrate arrays up to 1024 nano resonators with geometrical control and material uniformity at $\pm$20%, and to $\pm$1% with trimming and tuning.

Digital Control:

Jul 02	Demonstrate RF/analog functions using mixed-signal technologies.
Jun 03	Demonstrate MEMS tunable devices.