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RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)							DATE February 2007	
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA3 Advanced Technology Development				R-1 ITEM NOMENCLATURE Advanced Electronics Technology PE 0603739E				
COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	197.318	243.728	220.548	232.383	220.481	160.813	155.351	155.351
Centers of Excellence MT-07	5.050	5.625	4.000	0.000	0.000	0.000	0.000	0.000
MEMS and Integrated Microsystems Technology MT-12	47.090	55.562	54.470	54.362	59.962	60.262	55.262	55.262
Mixed Technology Integration MT-15	145.178	182.541	162.078	178.021	160.519	100.551	100.089	100.089

(U) Mission Description:

(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 processing 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 advanced product design capability and flexible, scalable manufacturing techniques will enable the commercial sector to rapidly and cost-effectively satisfy military requirements.

(U) The Microelectromechanical Systems (MEMS) and Integrated Microsystems Technology project is a broad, cross-disciplinary initiative to merge computation and power generation with sensing and actuation to realize a new technology for both perceiving and controlling weapons systems and battlefield environments. MEMS applies the advantages of miniaturization, multiple components and integrated microelectronics to the design and construction of integrated electromechanical and electro-chemical-mechanical systems to address 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. The MEMS project 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.

(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. 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

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platforms. The chip assembly and packaging processes currently in use, 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'. The ability to integrate mixed technologies onto a single substrate will increase performance and reliability, while driving down size, weight, volume and cost.

(U) The Centers of Excellence project finances demonstration, training and deployment of advanced manufacturing technology at Marshall University.

(U)	<u>Program Change Summary:</u> <i>(In Millions)</i>	<u>FY 2006</u>	<u>FY 2007</u>	<u>FY 2008</u>	<u>FY 2009</u>
	Previous President's Budget	220.877	248.627	236.675	225.765
	Current Budget	197.318	243.728	220.548	232.383
	Total Adjustments	-23.559	-4.899	-16.127	6.618
	 Congressional program reductions	 -13.200	 -11.424		
	Congressional increases	0.000	6.525		
	Reprogrammings	-4.700			
	SBIR/STTR transfer	-5.659			

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(U) Change Summary Explanation:

FY 2006	The decrease reflects the SBIR/STTR transfer, the Section 8040 rescission and the omnibus reprogramming.
FY 2007	The decrease reflects congressional cuts to Digital Control of Analog Circuits RF Front Ends, Analog Spectral Processors, ADNERF, High Gain Optical Transceiver on a Chip, Deep Ultraviolet Avalanche Photon Detectors, WIFI-EYEPOD, and a reduction for Section 8106 Economic Assumptions. These reductions are offset by congressional adds to Center for Advanced Microelectronics Manufacturing, Electronic Miniaturization, Enabling Ubiquitous Computing through Nanoscale Ultra-Low Power Electronics, and Mil-Tech Extension Technology Transition.
FY 2008	The decrease reflects completion of several efforts in Mixed Technology Integration Project (MT-15) including RF Front Ends, Ultra-Wide Band Technology, Liquid Electronics Advanced Power Sources and MEMS Electronic and Photonic Circuits in Silicon. These reductions have been partially offset by the continuation of the Advanced Manufacturing Technologies Center of Excellence.
FY 2009	The increase reflects exploration of new technologies in the MEMS and Integrated Micro-Systems Technology Project (MT-12) including Nano-Electro-Mechanical Computers and Microanalyzers.

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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-07				
COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Centers of Excellence MT-07	5.050	5.625	4.000	0.000	0.000	0.000	0.000	0.000

(U) Mission Description:

(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 facility and initiatives to local area industries to utilize computer-integrated manufacturing technologies and managerial techniques to improve manufacturing productivity and competitiveness. Training emphasizes technologies to significantly reduce unit production and life cycle costs and to improve product quality.

(U) Program Accomplishments/Planned Programs:

	FY 2006	FY 2007	FY 2008	FY 2009
Advanced Flexible Manufacturing	4.000	4.000	4.000	0.000

(U) Program Plans:

- Assess the Institute for Advanced Flexible Manufacturing's performance and transition from DoD to state/private support.

	FY 2006	FY 2007	FY 2008	FY 2009
Defense Techlink Rural Technology Transfer Project	1.050	1.625	0.000	0.000

(U) Program Plans:

- Continue to provide funding for the Defense Techlink Rural Technology Transfer Project.

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

- Not Applicable.

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COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
MEMS and Integrated Micro-systems Technology MT-12	47.090	55.562	54.470	54.362	59.962	60.262	55.262	55.262

(U) Mission Description:

(U) The Microelectromechanical Systems (MEMS) program is a broad, cross-disciplinary initiative to merge 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 applies 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.

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(U) Program Accomplishments/Planned Programs:

	FY 2006	FY 2007	FY 2008	FY 2009
Micro Power Generation	4.207	4.030	3.000	3.000

(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 will 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-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. The program will also explore innovative micro-scale, integratable power sources to provide high-density energy sources. The Micro Power Generation program is anticipated to transition via industry to dismounted warrior and unattended ground sensor network programs under development by the Army.

(U) Program Plans:

- Demonstrated capabilities in fuel processing, energy conversion to electricity, and thermal and exhaust management.
- Demonstrated MEMS micro heat engines utilizing micropower sources.
- Demonstrate integration of various power-generation components with microsensors and microactuators.
- Demonstrate stand-alone, remotely distributed microsensors and actuators with built-in power supply and wireless communication.
- Establish design paradigm-shifts that occur when implementing novel power sources at the micro-scale using MEMS technology.

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	FY 2006	FY 2007	FY 2008	FY 2009
Harsh Environment Robust Micromechanical Technology (HERMIT)	16.439	12.772	7.797	5.000

(U) The Harsh Environment Robust Micromechanical Technology (HERMIT) Program is developing micromechanical devices that can operate under harsh conditions- e.g., under large temperature excursions, large power throughputs, high g-forces, corrosive substances, etc. - while maintaining unprecedented performance, stability, and lifetime. Micromechanical RF switches are of particular interest, where sizable power throughputs and impacting operation constitute harsh operational environments. Other applications such as vibrating resonator reference tanks, gyroscopes, and accelerometers are also of interest. Among the HERMIT implementation approaches deemed likely to succeed are two of most interest: (1) wafer-level encapsulation or packaging strategies based on MEMS technology that isolate a micromechanical device from its surroundings while maintaining a desired environment via passive or active control; or (2) material and design engineering strategies that render a micromechanical device impervious to its environment, with or without a package (if possible). A key approach in this program that should allow orders of magnitude power savings is to selectively control only the needed micro-scale environment or volume via MEMS-enabled isolation technologies. The success of this program should enable a myriad of strategic capabilities including lower cost, more complex phased array antennas for radar applications; tiny frequency references with long- and short-term stabilities that greatly extend the portability of ultra-secure communications; and micro-scale inertial measurement units with bias stabilities approaching navigation-grade. The HERMIT program is anticipated to transition via industry to phased array antenna, reconfigurable communication front-end, seeker, and steerable aperture programs being developed by the Army, Navy, and Air Force, as well as to inertial navigation systems and Joint Tactical Radio System (JTRS) communications needed by these Services.

- (U) Program Plans:
- Establish the feasibility of encapsulating micromechanical devices under low-cost, wafer-level packages with minimal out-gassing or leaking and with minimal impact on device performance.
 - Demonstrate engineered materials and/or surface treatments that render a micromechanical device impervious to its surroundings or operating environment.
 - Demonstrate essential elements (e.g., thermistors, heaters, getters, etc.) needed for low power control of the operating environment surrounding a micromechanical device.

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- Demonstrate micromechanical devices (e.g., RF switches, vibrating resonators, etc.) fully integrated together with environment isolating measures (including circuits, if any) that maintain unprecedented performance, stability, and reliability, even under harsh environments.

	FY 2006	FY 2007	FY 2008	FY 2009
Chip-Scale Micro Gas Analyzers	14.946	13.930	12.315	10.362

(U) The Chip-Scale Micro Gas Analyzer Program will utilize the latest MEMS technologies to implement separation-based analyzers (e.g., gas chromatographs, mass spectrometers, poly-chromator-like devices) at the micro-scale to greatly enhance the selectivity of sensors to specific species, and thus, enable extremely reliable, remote detection of chemical/biological agents. The use of MEMS technology should also increase analysis speed and make possible the operation of such complex analyzer systems at extremely low power levels-perhaps low enough for operation as autonomous, wireless sensors. The many challenges in this program include the exploration and realization of micro-scale preconcentrator approaches, stacked gas columns, multiple sensor arrays, ionizers, vacuum pumps, and vacuum packaging. The success of this program will yield sensors substantially more selective than conventional sensors, again, making them particularly suitable for detection and identification of airborne toxins. The Chip-Scale Gas Analyzers program is anticipated to transition via industry to Chemical Warfare Agents (CWA) detector programs being developed by the Defense Threat Reduction Agency (DTRA) and the Army Soldier and Biological Chemical Command (SBCCOM).

(U) Program Plans:

- Establish design trade-offs in (column) length vs. species separation efficiency for micro-scale gas chromatographs, mass spectrometers, resonator-based separation mechanisms, etc.
- Demonstrate MEMS-enabled, micro-scale preconcentrators and explore the degree to which they enhance separation efficiency and species detectability.
- Demonstrate MEMS-enabled, micro-scale separation columns, ionizers, electromagnetic field generators, vacuum pumps, gas sensor arrays, calibration sources, all needed for separation-based analyzers.

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- Demonstrate advanced methods for making micromechanical sensor elements species sensitive (e.g., combinations of absorption spectroscopy and resonators coated with species-and-light sensitive films).
- Implement fully functional, MEMS-enabled gas separation analyzers with power consumptions small enough for autonomous, remote operation and control electronics integrated directly.

	FY 2006	FY 2007	FY 2008	FY 2009
MEMS Exchange	3.067	3.000	3.408	1.000

(U) This program seeks to provide flexible access to complex Microelectromechanical Systems (MEMS) fabrication technology in a wide variety of materials and to a broad, multi-disciplinary user base via the MEMS Exchange service. A major goal of the effort is to ensure self-sustained operation of MEMS Exchange after the end of the program by adding several process modules to the existing repertoire and increasing the number of processes run per year to raise revenues to the point of self-sufficiency. Among the future payoffs of this program is the establishment of an accessible infrastructure for low or medium volume production of MEMS-enabled products for DoD applications. The goal of the MEMS Exchange program is self-sufficiency at which point it will be able to provide MEMS fabrication services to all levels of industry and academia in support of Army, Navy, Air Force, and other DoD requirements without further DARPA sponsorship.

(U) Program Plans:

- Demonstrate online software capable of error checking and optimize process flow input by users to reduce the turn-around time per run and increase success rate.
- Insert a MEMS process module into the MEMS Exchange repertoire and make it available for use.
- Double the number of runs processed per year, to achieve a goal rate of 500 runs per year.
- Provide a modular merging process that combines modules together with transistor integrated circuits.
- Insert MEMS technology into three DoD applications using MEMS Exchange as the fabrication vehicle.

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	FY 2006	FY 2007	FY 2008	FY 2009
Low Power Micro Cryogenic Coolers	4.930	4.730	3.950	6.000

(U) The Low Power Micro Cryogenic Cooler program will attain superior performance in micro-scale devices (e.g. Low Noise Amplifier (LNA's) IR detectors, RF front-ends, superconducting circuits) by cooling selected portions to cryogenic temperatures. The key approach in this program that should allow orders of magnitude power savings is to selectively cool only the needed volume/device via MEMS-enabled isolation technologies. Such an approach will benefit a large number of applications where performance is determined predominately by only a few devices in a system, e.g., communications where the front-end filter and LNA often set the noise figure; and sensors, where the transducer and input transistor in the sense amplifier often set the resolution. MEMS technology will also be instrumental for achieving micro-scale mechanical pumps, valves, heat exchangers, and compressors, all needed to realize a complete cryogenic refrigeration system on a chip. Transition of this technology is anticipated through industry, who will incorporate elements of the technology in current and future weapon system designs.

(U) Program Plans:

- Obtain high thermal isolation using MEMS technology, despite high surface-to-volume ratios of micro-scale elements.
- Demonstrate micro-scale compressors with sufficient efficiency for low power operation.
- Demonstrate heat exchangers, Joule-Thompson plugs, valves, pumps, all needed for cryo-cooler implementation.
- Integrate micro cooler components together with sufficiently isolated devices to-be-cooled to yield a single chip system.

	FY 2006	FY 2007	FY 2008	FY 2009
Chip-Scale Atomic Sensors	3.501	9.000	9.000	8.000

(U) The Chip-Scale Atomic Sensors program will develop universally reconfigurable microsensors (e.g., for magnetic fields, temperature, pressure) with unmatched resolution and sensitivity. These devices will use the latest in MEMS and photonic technologies to harness perturbations in atomic transitions as the sensing and measuring mechanisms for various parameters. Currently, some of our best sensors achieve their performance via readout mechanisms based on the frequency of mechanical resonators, which can be determined with high resolution. Chip-

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scale atomic sensors would work on a similar principle, still using a time or frequency-based readout, but with substantially better resolution enabled by their much more stable atomic-clock-like readout. Furthermore, such sensors can be made reconfigurable by merely switching to atomic transitions that are strongly susceptible to certain stimuli, but insusceptible to others. If successful at achieving a universal sensor, the Chip-Scale Atomic Sensor program would not only provide sensors with unmatched performance, but would also be the key to lowering the cost of such sensors, since the production volumes for a universal sensor should be enormous. Interdisciplinary teams of fundamental technology developers and sensor integrators will be formed to transition the technology to DoD systems.

(U) Program Plans:

- Develop a tunable microwave local oscillator to excite and select different hyperfine transitions.
- Integrate sensing transducers into atomic cells.
- Develop atomic cell wall coatings to mitigate the need for high cell pressure.

	FY 2006	FY 2007	FY 2008	FY 2009
Site-Specific Thermal Management (SSTM)	0.000	3.000	5.000	6.000

(U) The Site-Specific Thermal Management (SSTM) program will develop new approaches to removing local hot-spots that limit the performance of high-speed signal processing electronics, radar imaging systems, optoelectronic devices, and other systems characterized by above-ambient thermal issues. This program will provide a natural complement to the Low Power Micro Cryogenic Coolers program by addressing the performance-critical issue of excessive heat removal. The SSTM program will consider both monolithic and heterogeneous thermal management approaches based on variety of thermal materials and heat removal methods. Examples include self-powered liquid spray cooling, integral copper heat pipes, microfluidic channels and diamond interposer layers. This technology is lowering power consumption and overall cooling requirements and will be inserted through DoD industrial firms into future DoD systems.

(U) Program Plans:

- Identify and apply new integrated technologies for the thermal management of microsystems.
- Develop and integrate cooling approaches using new materials.

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	FY 2006	FY 2007	FY 2008	FY 2009
Micro-Beam Clocks	0.000	4.000	5.000	7.000

(U) The Chip Scale Atomic Clock (CSAC) program (budgeted in PE 0602716E, Project ELT-01) will demonstrate the potential of shrinking high precision time references by exploiting advances in micromachining, photonics, and electronics technology. The Micro-Beam Clock program will extend the accuracy of miniature clock by exploiting the precision of nuclear particle transport. The concept of beam clock has been known at least since the 1960's but has not been widely pursued due to the difficulty in containing a large volume of xenon gas. This problem will be addressed by going to the micro-scale. Miniaturization of the conventional beam clocks with major innovations are possible due to microscale implementation – microscale xenon atom source, micromachined permanent magnets, and micromechanical atom flux detectors. This approach will not only improve the stability over existing CSAC but will further reduce the required power. This technology will be transitioned into DoD systems through innovative companies, including performers under the Chip-Scale Atomic Clock program.

(U) Program Plans:

- Generate sufficient atom flux using adsorption-desorption control at microscale.
- Detect atoms in flight using micro-cantilever array – Brownian noise limited.
- Determine permanent magnet laser cutting at microscale.
- Determine High B-field gradients at microscale.
- Determine pressure measurement in presence of high magnetic field with MEMS pressure sensors.

	FY 2006	FY 2007	FY 2008	FY 2009
Nano-Electro-Mechanical Computers (NEMS)	0.000	0.000	2.500	4.000

(U) The goal of this program is to develop nanoscale mechanical switches and gain elements integrated intimately with complementary metal-oxide semiconductor switches. One mechanical switch per transistor will enable the transistor to operate at near zero leakage powers, enabling pico or femtowatt standby operation. The program will also develop mechanical gain elements using physical effects such as giant

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magnetoresistance, buckling, electromechanical phase transitions, van der Waals forces, and Casimir forces to enable very low-noise, high-frequency amplifiers for low-power, low-noise analog signal processing. Possibilities of using mechanical power supplies and mechanical vibrating clocks could enable electronics that are less susceptible to electromagnetic pulse attacks. Enabling of nanomechanical elements in direct band gap materials will circumvent problems of gate oxide stability, allowing fast logic with optics functionality.

(U) Program Plans:

- Develop nanomechanical switch-based logic in semiconductors, metals and insulators.
- Develop mechanical gain elements for analog amplification using effects such as buckling and electromechanical phase changes.
- Develop NEMS switches in direct bandgap materials to enable optical functionality with switches.

	FY 2006	FY 2007	FY 2008	FY 2009
MicroAnalyzers	0.000	0.000	2.500	4.000

(U) The MicroAnalyzers program will apply recent developments in nanotechnology and MEMS to realize tiny, fast, ultra-low power liquid analyzers. Adopting a similar Micro-Gas Analyzers (MGA) theme of staged preconcentration, separation, and detection, MicroAnalyzers will develop MEMS sample collection and nanotechnology clean-up modules along with preconcentrators, separators, and chip-scale mass spectrometers specifically designed for liquids. Specific applications of these liquid analyzer efforts are: 1) rapid screening for trace contaminants in the water supply; 2) detection of water-born biological warfare (BW) agents; and 3) identification of trace chemical signatures associated with the manufacture of explosives and weapons of mass destruction (WMD).

(U) Program Plans:

- Develop compact, autonomous, deployable liquid analysis systems capable of identifying contaminants and toxins in water supplies, presence of Biological Warfare (BW) agents and chemical signatures associated with the manufacture and proliferation of explosives.
- Deploy remote collection of water samples.
- Sample clean-up and subsequent preconcentration of chemical substances of interest.

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	FY 2006	FY 2007	FY 2008	FY 2009
Center for Advanced Microelectronics Manufacturing	0.000	1.100	0.000	0.000

- (U) Program Plans:
- Develop advanced microelectronics manufacturing processes.

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

- Not Applicable.

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COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Mixed Technology Integration MT-15	145.178	182.541	162.078	178.021	160.519	100.551	100.089	100.089

(U) Mission Description:

(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. 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), microphotronics, 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) The field of 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 ‘matchbook-size’, highly integrated device and microsystem architectures. Examples of component-microsystems include low-power, small-volume, lightweight, microsenors, microrobots and microcommunication systems that will improve and expand the performance of the warfighter, military platforms, munitions and Unmanned Air Vehicles (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, microphotronics, microelectronics and 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

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technologies onto a single substrate will drive down the size, weight, volume, and cost of weapon systems while increasing their performance and reliability.

(U) Program Accomplishments/Planned Programs:

	FY 2006	FY 2007	FY 2008	FY 2009
Digital Control of Analog Circuits (Formerly RF Front Ends)	0.542	2.500	0.000	0.000

(U) Digital Control of Analog Circuits will demonstrate analog/radio frequency (RF) electronic components that have the ability to self-assess and adapt in real time (sub microseconds), by self-tuning their impedance-matched networks and thereby extending the operational performance of analog components to the intrinsic 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. This program will transition via industry in the form of integrated adaptive RF front-end components for a wide variety of applications used by the Services and intelligence agencies, particularly radar, space based communication, smart weapons, and electronic warfare systems.

(U) Program Plans:

- Demonstrate real-time active self-assessment and monitoring of RF/analog functions using nano-Complimentary Metal Oxide Silicon (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.
- Develop techniques and algorithms to monitor active device status.
- Demonstrate MEMS tunable device optimization (<1 microsecond, 10:1 tuning ratio).
- Fabricate tunable MEMS control integrated circuits.
- Fabricate self-assessment control integrated circuits.
- Demonstrate device and algorithm concepts for intelligent self-assessment of analog functions.
- Demonstrate device concepts for 10⁵ microsecond actuation time of impedance matched networks.
- Complete design concept for adaptable RF components.

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- Demonstrate concept of digital assessment of analog device.
- Validate concept of adaptable RF components by demonstrating digital control of analog circuits.

	FY 2006	FY 2007	FY 2008	FY 2009
Optical Code Division Multiple Access (OCDMA)	6.380	0.000	0.000	0.000

(U) Optical CDMA represented a paradigm shift from the current Wavelength Division Multiplexing/Time Division Multiplexing (WDM/TDM) optical networks. Instead of assigning a wavelength and a time slot to a user, O-CDMA assigned a code to a user. The goal of this program was to demonstrate technology for an advanced O-CDMA communications system. Such a system potentially offered the benefit of multi-level security, low probability of interception, detection and jamming, decentralized network, and higher spectral efficiency. The O-CDMA program was anticipated to transition via industry to optical networking programs of interest to all Services.

(U) Program Plans:

- Demonstrated data transmission between 10 simultaneous users at 10 Gigabit/second per user with a low bit error rate.
- Demonstrated scalability to 100 simultaneous users and cardinality of 1000.
- Demonstrated spectral efficiency scalable to 1 bit/s-Hz.

	FY 2006	FY 2007	FY 2008	FY 2009
Large Area Distributed Macroelectronics	6.100	0.000	0.000	0.000

(U) The Large Area Distributed Macroelectronics program developed large area multifunctional actuation and sensing systems using novel combinations of active and passive electronics and flexible, conformable, non-traditional materials and techniques. It developed basic technologies and techniques for component attachment, electrical interconnections, and multilayer routing utilizing existing novel materials and designs for actuation and sensing such as electroactive polymers to achieve active porosity and fibers for acoustic response. The program demonstrated prototype systems that achieved orders of magnitude improvements in performance and/or cost. Examples of applications include:

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control surfaces for an autonomous precision guided parafoil and controlled air boundary layers for reduction in drag for underwater vehicles; beam steered acoustic arrays with large apertures to achieve order of magnitude improvements in angle of coverage and signal to noise ratios; early warning threat detection and localization using a large area inflatable structure with woven antennas and electronics for high bandwidth communications; and aircraft or UAV wing skins for chem/bio monitoring. This effort will transition through industry for active circuit applications.

(U) Program Plans:

- Developed enhanced transistors compatible with low cost, large area fabrication.
- Developed methods to print active circuits on large area and flexible circuits.
- Developed techniques to wirelessly communicate between circuit blocks over a distributed electronics surface.
- Developed novel circuit/microarchitectures to enhance system performance for demanding electronic applications.
- Demonstrated examples of large area and/or flexible substrate distributed electronics to address difficult problems in sensor networks, physical security systems, or radar beam forming/steering.

	FY 2006	FY 2007	FY 2008	FY 2009
Adaptive Photonic Phased Locked Elements (APPLE)	9.546	11.512	10.000	9.000

(U) The goal of this program is to demonstrate a fully scalable and modular architecture of phased sub-apertures capable of producing an arbitrarily large optical aperture that can be rapidly and non-mechanically steered over a wide field of regard with high precision. This effort is anticipated to transition via industry for potential laser systems and space based applications.

(U) Program Plans:

- Develop sub-apertures to operate at wavelengths of 1.06 um, 1.55 um, 3-5 um, and 8-12 um.
- Demonstrate steering over a full 90-degree cone.
- Reduce parts counts, which will make certain laser systems affordable.
- Reduce weight, a particularly important goal for space-based applications.

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- Develop and test a single APPLE aperture at the 50 watt optical power level.
- Introduce and verify a new material system for optical phased arrays and adaptive optical actuators to support the development path to higher power handling capability.
- Demonstrate by analysis the path to much lower loss electronic beam steering.
- Demonstrate by a combination of direct component measurements and advanced system modeling that an electronic beam control system, with optical loss of less than 2 dB, is feasible and supported by the development path.

	FY 2006	FY 2007	FY 2008	FY 2009
Data in Optical Domain Network (DoD-Network)	11.838	12.299	9.200	0.000

(U) Currently optical networks use photonics to transport data and electronics to process data. However, as the underlying bit rates of the optical networks are pushed beyond 40 giga-bits per second, there will be significant processing bottlenecks in these networks and these bottlenecks will severely limit the military's ability to rapidly transport time critical information. A potential solution to this problem is to develop photonic technology so optics can take over higher order network processing functions. The DoD-Network program will develop and demonstrate four key photonic technologies to meet these challenges: all-optical routing, all-optical data buffering (controllable and eventually random access), optical logic and circuits, and all-optical (multi-wavelength) regenerators. These photonic technologies will lead to intelligent all-optical networks. The program will have two major areas of interest: The first will focus on developing new photonic technology that is essential if photonics is to play a significant role in higher order processing in optical networks. The second area will focus on developing novel architectures that will fully exploit the new photonic technology to bring new and increased functionalities to the optical networks. The DoD-Network program is anticipated to transition via industry to high speed, high capacity optical networking programs of interest to the Air Force.

- (U) Program Plans:
- Develop a limited (4x4 or 8x8) optical packet switch.
 - Develop means for address processing.
 - Develop multi-wavelength optical regenerators.
 - Develop flexible, room temperature optical buffers.

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- Develop synchronization techniques for short pulses.
- Develop controllable picosecond optical time delays.

	FY 2006	FY 2007	FY 2008	FY 2009
Microantenna Array Technology & Applications (MIATA)	8.645	7.117	0.000	0.000

(U) The goal of the MIATA program is to develop low-cost arrays that can sense both Millimeter Wave (MMW) and infrared (IR) scenes along with compact MMW designator sources for passive and active imaging applications in the spectral region from W-band (94 GHz) to the long wave infrared optical region. New micro- and nano-fabrication techniques of low cost antenna arrays provide a basis for revolutionary tactical military applications in the unexploited submillimeter to long wave optical spectral region. The military utility of this technology includes conventional passive imaging with compact devices at elevated temperatures, passive or active ballistic imaging through extreme weather and obscurants, polarization discrimination of manmade objects, rapid electronic spectral tuning for clutter discrimination, ultrawideband response (achieved using metal-insulator-metal tunneling structures for sensing/rectifying the antenna current), and may also include synthetic apertures, phased arrays, true time, and steered receiver beams. The MIATA program is planned for transition to the Army Research Laboratory at the conclusion of Phase 2, which is anticipated to be completed in FY 2007.

(U) Program Plans:

- Achieve 95 GHZ: Noise Equivalent Temperature Detection (NETD) $\leq$ 20 Kelvin (K) in a 2x2 array.
- Achieve 8-12 um: NETD $\leq$ 0.1 K in an 8x8 array.
- Achieve 95 GHZ: NETD $\leq$ 2 K in an 8x8 array.
- Achieve 8-12 um: NETD $\leq$ 0.02 K in a 64x64 array.

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	FY 2006	FY 2007	FY 2008	FY 2009
Ultra-Wide Band Technology	17.239	10.500	0.000	0.000

(U) Radar array antennas that use the Ultra-Wide Band hold the promise of a new class of high coverage/high sensitivity systems. DARPA is tackling the issue through Ultra-Wide Band Multi-Function Photonic Transmit and Receive (ULTRA T/R) Modules.

(U) The objective of the ULTRA T/R program is to develop a wideband microwave antenna interface and corresponding antenna elements that would replace the conventional electronic T/R module-antenna combination and offer multiple modes of operation (e.g. simultaneous transmit and receive or switched mode), fiber interface to/from either digital or analog beamformer at significantly reduced size, weight, and power. The ULTRA T/R program is planned for transition to Navy and Air Force airborne C4ISR platforms and wideband phased-array antenna systems at the conclusion of Phase III, which is anticipated to be completed by FY 2007.

(U) Program Plans:

- Ultra Wide Band Multi-Function Photonic T/R Module
 - Develop and demonstrate optical modulators, which exhibit low switching voltages and incorporate a long effective electrode length.
 - Fabricate and demonstrate high power photodiodes and photodiode arrays for T/R modules.
 - Develop a high-efficiency, high-power, low Relative Intensity Noise (RIN) laser operating at 1550 nm.
 - Develop high antenna T/R isolation through a) low return loss at the modulator/antenna interface; and b) low mutual coupling between antenna elements.

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	FY 2006	FY 2007	FY 2008	FY 2009
Laser-Photoacoustic Spectroscopy (L-PAS)	8.747	8.190	6.095	0.000

(U) The goal of this program is to develop and demonstrate highly sensitive, compact, rapid, reliable, inexpensive, and low power consuming chemical agent sensors based on the principle of laser photoacoustic spectroscopy. The L-PAS sensor will be able to discriminate a wide variety of possible chemical agents, explosives, and narcotics in the presence of diverse background environments. L-PAS will transition prototype chemical agent sensors to the Joint Science and Technology Office (JSTO), Defense Threat Reduction Agency, for evaluation. To that end, JSTO and DARPA are working closely to ensure that the final program metrics are properly aligned with the joint Chemical/Biological community needs.

(U) Program Plans:

- Demonstrate working prototypes that have a sensitivity to <1ppb at a false alarm rate of better than 10^{-6} .
- Demonstrate a major improvement in performance (measured in terms of sensitivity) over the Joint Chemical Agent Detector (JCAD) system, which is the next generation chemical sensor currently under development.

	FY 2006	FY 2007	FY 2008	FY 2009
High Operating Temperature - Mid-Wave Infrared (HOT MWIR)	11.035	13.811	13.468	0.000

(U) The objective of this program is to establish technology for high-speed sampling and high spatial resolution infrared focal plane arrays that operate in the mid-wave infrared without cryogenic cooling. The high sampling speed is required for both threat detection and for imaging from fast moving platforms. Technology goals are to achieve greater than an order of magnitude reduction in currents contributing to detector noise demonstrated with a high density, large area detector array format of up to 1280 x 720 elements. For imaging, the sensor will respond in a broad spectral band, including the mid and long wave infrared, and optimized for imaging at high frame rates with large field of view. This program is anticipated to transition via industry for applications such as multi-band mid-wave or micro-detectors.

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- (U) Program Plans:
- Design new approaches necessary to reduce detector dark current and noise.
 - Amplify the low level signal in multi-band mid-wave detectors.
 - Develop micro-detectors, which collect signals from a large area while reducing the volume available for detector noise current generation.
 - Demonstrate carrier extraction techniques in the laboratory to show potential excess current while maintaining high signal levels.
 - Develop noise suppression techniques to solid state cooler design to reduce operating temperature without increasing power to the cooler.

	FY 2006	FY 2007	FY 2008	FY 2009
Liquid Electronics Advanced Power Source (LEAPS)	11.000	10.575	0.000	0.000

(U) This program will develop technology to support direct nuclear-to-electrical conversion in which a liquid semiconductor (LSMC) is used as a self-healing medium for capturing the energy of fission fragments in the form of electron-hole (e-h) pairs, and a collector of the e-h pairs. The liquid semiconductor will also serve as a medium in which to contain and disperse the nuclear fuel energy conversion. A general study of electronics based on liquid semiconductors will be included in this program. LEAPS is transitioning through industry teams involved in the manufacture of self-healing liquid semiconductor material and devices. These teams include technology vendors who intend to bring products to market as a result of this research.

- (U) Program Plans:
- Develop the liquid semiconductor-based nuclear source and reactor.
 - Implement a direct conversion cell using liquid semiconductor materials.
 - Develop liquid semiconductors as self-healing materials for high stress environments.

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	FY 2006	FY 2007	FY 2008	FY 2009
Visible/Short Wave IR - Photon Counting	5.402	9.027	7.912	5.000

(U) This program will develop imaging over a broad spectral band at extremely low levels of ambient illumination to provide a unique capability for remote sensing, unattended sensors, and pay-loads for autonomous ground and air platforms. Recent innovations in solid state imaging devices, including parallel processing at the pixel level and novel read read-out technology, can contribute to development of a new class of sensors, which can create an image with only a few photons per pixel, exceeding performance of current low light level imagers. The direct conversion of low light level information into an electronic format provides access to a suite of signal processing, image enhancement and communications techniques not available with current low light level imaging devices. This program will transition via industry for ultraviolet to infrared imaging applications.

(U) Program Plans:

- Develop unique electronic read-outs with internal gain that boost low level signals above output amplifier noise.
- Develop potential approaches to include distributed amplification in the read-out signal chain, avalanche multiplier gain internal to the pixel, and semiconductor optical amplification integrated with the detector.
- Extend silicon detector response into the near infrared by doping with narrow band gap materials to achieve a single imaging chip with response from the ultraviolet to near-infrared.
- Integrate with uncooled long wavelength infrared imagers through development of technology to transfer the thin film silicon onto the infrared imager, achieving an imaging chip with broadband response and photon counting sensitivity from ultra-violet to the infrared.

	FY 2006	FY 2007	FY 2008	FY 2009
Electronic & Photonic Integrated Circuits on Silicon (EPIC)	17.428	12.970	7.223	5.000

(U) This program will develop two critical alternative photonic technologies based on silicon substrates. The first thrust addresses active photonic components based on silicon, which do not rely on generating light within the material. While passive photonic components, such as

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waveguides, can be fabricated from silicon, silicon's indirect bandgap does not lend itself to fabricating active photonic components based on the generation of photons (lasers, amplifiers etc.). The first alternative technology development will be optical amplifiers using Raman gain. Fiber amplifiers based on Raman gain currently play a major role in optical networks, and demonstrating this optical amplification in silicon will be a major step toward overcoming on-chip losses in complex chip-scale optical components. The second alternative technology development will address optical transistor action, or switching, in silicon, (i.e., a three-terminal optical device in which control photons at one terminal will make a large change in the photons transmitted between the other two terminals). Taken together, these two capabilities will create a new paradigm in which silicon will provide a platform for monolithic integration of photonic and electronic functions. The EPIC program is anticipated to transition via industry to optical communication and electronic warfare programs of interest to all Services.

(U) Program Plans:

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

	FY 2006	FY 2007	FY 2008	FY 2009
Space, Time Adaptive Processing (STAP) BOY	4.356	6.240	4.240	0.000

(U) This program will research, develop, and demonstrate miniature, low-power, low-cost, teraflop-level signal processing solutions derived from commercial Graphics Processor Unit (GPU) hardware and software of the type currently used for fast geometry computations in hand-held electronic games like Nintendo's GAME BOY®. Success in this program will allow the DoD to exploit the continuing phenomenal growth in both performance and programmability of GPU's resulting from competition in the multi-billion dollar international electronic entertainment industry. Particularly relevant advantages of recent GPU's over more traditional embedded processors include enhanced memory access bandwidth, hardware-accelerated floating-point vector geometry functions, low power consumption, and open source programming language support. The STAP BOY technology is planned for transition to the Army at the conclusion of Phase III, which is anticipated to be completed in FY 2008.

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(U) Program Plans:

- Develop and characterize a prototype architecture using a single GPU and a Field Programmable Gate Array (FPGA) input-output structure.
- Demonstrate that the prototype system is capable of sustaining 100 Gflops potentially scalable to a multi-GPU pipeline mesh teraflop computing architecture, and is easily programmable to provide extremely high performance in diverse challenge problems.
- Demonstrate the single GPU prototype consisting of 1) adaptive algorithm for data structure simplification, suitable for adaptive weight computations in STAP and 2) 3-D tomographic reconstruction processing for aperture synthesis.

	FY 2006	FY 2007	FY 2008	FY 2009
Vertically Integrated Sensor Arrays (VISA)	8.270	11.000	7.000	6.000

(U) The Vertically Integrated Sensor Arrays (VISA) program addresses new architectures for three-dimensional focal plane arrays, where multiple levels of signal processing are integrated into each pixel in the array. This novel infrared focal plane architecture will be expanded to include multiple processing layers, higher density “vias” at the pixel, and coverage of a broad spectral band from the visible to the infrared. This increased on-chip processing power will enable new capability for smart sensors, such as high speed imaging, on-chip threat discrimination and anti-jamming. The VISA technology establishes a dramatically new approach to read-out electronics for imaging sensors, impacting multiple areas essential to Defense systems. The three-dimensional read-out architecture allows increased on-chip charge integration, dynamic range of eighteen to twenty bits, simultaneous registration of multiple wavelength bands, and high speed laser imaging. Specific system impacts include Mid/Long-wavelength target acquisition systems for air and ground; smart missile seekers, and anti-jamming, and imaging through high intensity sources. This program will transition through parallel efforts involving industry, universities, and other not for profit organizations to develop vertical interconnect techniques and novel read-out architectures and circuits to be incorporated in DoD systems.

(U) Program Plans:

- Demonstrate high dynamic range imaging sensors with an analog to digital converter at each pixel in the array.
- Design and develop three-dimensional focal plane architecture with multiple levels of signal processing at each detector in the array.
- Develop thru-via and interconnection technology with greater than 99% operability on 256x256 arrays.

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- Demonstrate increased sensitivity realized by the large charge storage capacity of the three-dimensional focal plane circuit architecture.
- Develop low mass structures and high-Q resonators.
- Develop nanoparticle mass-load tags for enhanced sensitivity.

	FY 2006	FY 2007	FY 2008	FY 2009
Analog Spectral Processors	0.000	4.500	8.483	9.979

(U) The Analog Spectral Processors (ASP) program will leverage existing MEMS capabilities to make precision RF components, and perform low-insertion-loss/heterogeneous components integration to demonstrate integrated Analog Spectral Processors that greatly reduce dynamic range and bandwidth required on A/D converters and other front-end components. This will enable proliferation of advanced RF capabilities to the individual war fighter by dramatic reduction in size, weight, and power of RF systems. Industrial firms that are currently the major suppliers of radio equipment for defense and homeland security applications will serve as the primary transition partners upon successful completion of the program.

(U) Program Plans:

- Demonstrate large scale heterogeneous integration of MEMS resonators, MEMS switches, and RF active components to enable Analog Spectral Processor Front-Ends capable of arbitrarily sampling across at least three decades of bandwidth and dynamically compressing spectrum in terms of bandwidth and dynamic range so as to present only signals to the Analog Digital Converter.
- Demonstrate filter arrays.
- Demonstrate ASP.

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	FY 2006	FY 2007	FY 2008	FY 2009
All-Dielectric Non Electronic RF Front-End (ADNERF)	0.000	3.500	5.000	6.500

(U) The All-Dielectric Non Electronic RF Front-End (ADNERF) program will create a wide bandwidth, tunable RF front end technology that is immune to electromagnetic pulse attack. This program will seek an entirely new approach to RF front-end technology where all metal and front-end electronic circuitry are eliminated. Of particular interest will be an all-dielectric, electronics-free RF front end with sensitivity and dynamic range consistent with today's wireless communication and radar systems. By eliminating the metallic antenna, a secondary goal is to effect a significant reduction in detectable radar cross section.

(U) All-Dielectric, Non-Electronic RF Front Ends (ADNERF) represent the ultimate solution for protecting wireless communication and radar systems. ADNERF can find immediate application protecting tactical communication and radar systems, which are highly vulnerable to electromagnetic pulse (EMP) attack due to their close proximity to enemy assets. As the efficiency and tunability of the all-dielectric non-electronics front-ends improve, the technology can become an ubiquitous RF front end for all military as well as commercial wireless devices, providing the communications infrastructure immunity against EMP attacks. This program will transition through industry performers involved with reducing the susceptibility of electronics to damage from high electro-magnetic pulse weapons.

(U) Program Plans:

- Identify and develop innovative dielectric materials with high dielectric constant and low loss.
- Design and implement doubly resonant (RF and optical) antenna structures in support of non-electronic signal transduction.
- Demonstrate dramatic reduction in RF front end susceptibility to electromagnetic pulses while maintaining militarily useful system.

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	FY 2006	FY 2007	FY 2008	FY 2009
High Gain Optical Transceiver on a Chip	0.000	3.500	6.000	7.500

(U) The High Gain Optical Transceiver on a Chip program will address development of an ultra-compact, low power, solid state laser transceiver-on-a-chip (source and receiver), achieving with integrated circuit technology, the peak energy and narrow pulse width required for high resolution imaging. Two technical innovations will contribute to this new capability, large arrays of vertical cavity surface emitting lasers (VCSEL) integrated into a micro-chip; and the incorporation of high gain at receiver, specifically semiconductor optical amplifiers integrated with the detector to boost the laser signal return above receiver noise. The high optical gain at the receiver will add flexibility to trade-off laser power for solid state optical gain, and the capability to illuminate targets with extremely low optical power, providing a nearly-covert optical signal. Wavelength diversity augments the capability to illuminate difficult to detect optical signals.

(U) Currently, diode pumped lasers will require high peak energy to achieve 20 to 100 mj with the narrow pulse width (1 – 10 nsec) needed for imaging and targeting applications. These laser systems will be dramatically simplified with solid state arrays and have the potential to reduce size of these lasers from several pounds to a few ounces while at the same time significantly increasing overall efficiency to as high as 80%. The solid state arrays avoid the efficiency loss in coupling optical energy into the gain medium, and eliminate conversion loss in the gain medium as well. This program will transition through industry performers into DoD systems by putting laser illuminating imaging into the hands of individual warfighters, allowing integration into small robotic platforms and micro-air vehicles.

(U) Program Plans:

- Achieve the extremely high peak power required for imaging and targeting applications via design, integration, and packaging.
- Re-design VCSEL arrays to achieve the closed packaged density consistent with compound semiconductor manufacturing.
- Demonstrate high peak energy per pulse at narrow pulse width, which requires both design and processing innovations to realize the interconnection of thousands of individual elements, while achieving the rapid response necessary for narrow pulses.
- Demonstrate improvements in individual device design specifically tailored for pulse mode operation that are necessary to achieve the high peak power required for imaging and ranging applications, which include novel cavity materials, reflective layers, spacing.
- Achieve thermal stability via device mounting and heat sinking.

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- Develop complementary process for the semiconductor optical amplifier.
- Develop array compatible semiconductor optical amplification technology to achieve gain at the detector with the resolution required for imaging.
- Amplify low level optical returns with minimum excess noise while maintaining uniformity across the array.

	FY 2006	FY 2007	FY 2008	FY 2009
Maskless Direct-Write Nanolithography for Defense Applications	0.000	24.000	21.000	24.000

(U) This program will develop a maskless, direct write lithography tool that will address both the DoD's need for affordable, high performance, low volume Integrated Circuits (ICs) and the commercial market's need for highly customized, application-specific ICs. In addition, this program will provide a cost effective manufacturing technology for low volume NanoElectroMechanical Systems (NEMS) and Nano Photonics initiatives within the DoD.

(U) Maskless lithography tools, installed in the Trusted Foundry and in commercial foundries, would enable incorporation of state-of-the-art semiconductor devices in new military systems, and allow for the cost-effective upgrade of legacy military systems.

(U) Program Plans:

- Develop a maskless, direct write lithography tool that will address both the DoD's need for affordable, high performance, low volume ICs and the commercial market's need for highly customized, application-specific ICs.
- Determine a cost effective manufacturing technology for low volume NanoElectroMechanical Systems (NEMS) and Nano Photonics initiatives within the DoD.
- Enable incorporation of state-of-the-art semiconductor devices in new military systems, and allow for the cost-effective upgrade of legacy military systems.

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	FY 2006	FY 2007	FY 2008	FY 2009
Stand-off Detection and Identification	0.000	6.000	8.000	6.000

(U) The Stand-off Detection and Identification program will detect and identify explosive threats at a stand-off distance, which is critical to force protection in all military operations, especially in urban scenarios. Multiple techniques will be available for detection, but no single technique provides both high probability of detection with low false alarm rate, and identification of specific characteristics of the threat. A micro-system approach with multiple, synergistic sensor technologies integrated in a compact package, will be critical to wide spread deployment of this sensor capability.

(U) The microsystem approach involves the identification of significant attributes from multiple non-over-lapping perspectives, such as shape and chemical signature, at stand-off ranges of fifty meters to potentially one hundred meters. This presents major challenges in imaging through opaque media; identifying signatures in parts per billion in high background ambient; selecting specific wavelength bands of interest; and the signal/imaging processing required for positive identification. The system configuration presents additional integration challenges for potential application in manportable systems or small autonomous vehicles. This program will transition through industry performers into DoD systems aimed at developing stand-off x-ray imaging devices for robotic vehicles.

(U) Program Plans:

- Develop unique imaging techniques suited to imaging through visually opaque objects at a 50-100 meter stand-off distance.
- Investigate multiple imaging approaches including integration of typically disparate techniques such as passive infrared and radio frequency with active techniques, laser imaging and high energy active imaging techniques, x-ray imaging.
- Implement x-ray imaging and develop compact package for remote vehicle applications. X-ray source requirements, such as power, size, weight, focal spot, tube configuration including various beam formation techniques must be investigated to efficiently transmit radiation over the stand-off distance. Source requirements will be traded-off for more efficient sensor technology, notably two dimensional arrays of cadmium telluride or silicon carbide with high spatial resolution.
- Identify particular effluents, which requires development of unique spectrometer-on-a-chip sensor concepts that cover a broad spectral range.

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- Investigate excitation sources and tunable sensors from the far-infrared through millimeter wave spectral regions.
- Address issues including efficient radiation coupling into the sensor, spectral selectivity, signal enhancement techniques.

	FY 2006	FY 2007	FY 2008	FY 2009
Deep Ultraviolet Avalanche Photon Detectors	0.000	3.500	4.597	5.302

(U) Recent advances in Wide Bandgap Semiconductor materials have opened new possibilities for exploiting the ultra-violet region of the electromagnetic spectrum. The current Semiconductor Ultra Violet Sources (SUVOS) program has been successful in advancing the state of the art of Ultra Violet (UV) light emitting diodes and laser diodes. This follow-on program seeks to develop high sensitivity, compact ultra violet detectors. Specifically, avalanche photodiodes will be developed to detect single photons. These UV detectors will dramatically improve the performance and reduce the size and weight of the biological warning detectors under development in the SUVOS program. They will also increase the range and data rate of covert UV communications systems. This program will transition through industry and university performers developing compact, reliable, and cost-effective photodetectors for a variety of military applications.

(U) Program Plans:

- Develop high sensitivity, compact ultra violet detectors.
- Develop avalanche photodiodes that can detect single photons.
- Improve the performance and reduce the size and weight of the biological warning detectors under development in the SUVOS program.
- Reduce the defects by orders-of-magnitude and develop highly doped cladding layers.
- Optimize the detector response and switching speed.

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	FY 2006	FY 2007	FY 2008	FY 2009
WIFI-EYEPOD	0.000	3.000	4.860	7.240

(U) The WIFI-EYEPOD program will transform the dismounted soldier into a semi-autonomous Direct Current (DC) - 10 GHz sensor/comms/SIGINT platform using a personal digital assistant (PDA) modified with a broadband multifunctional RF sensor plugged into its universal serial bus (USB) port. Combined with the current DARPA STAP-BOY program, or even a standard laptop, the RF-EYEPOD enhancement will enable real-time local processing for extremely time-sensitive and perishable data requiring immediate processing and response. The WIFI-EYEPOD RF sensor may be used to control and or hunt near field enemy WIFI and communications networks allowing the soldier to virtually see enemy combatants communicating and setting up attacks, hiding behind walls and in buildings mixed with non-combatants. Working in small networks will permit instantaneous location(s) of sniper fire and gunfire for retribution, and positions of tactical squad members relative to inside and outside of buildings, without detection by enemy sensors.

(U) In addition to adding RF-sensory and networking capability to PDAs and vehicle-mounted information processing hardware, the WIFI-EYEPOD will provide secure communications and networking capability so that the processed information can be compressed and downloaded real-time to larger, holistic sensor integration systems, providing micro-detail to create macro understanding at the unit and division command levels. Transition targets are through Army PM Soldiers Systems and USMC ground forces.

(U) Program Plans:

- Develop, integrate and optimize diverse system capabilities into a single low cost miniature package with a cost target at less than \$1 thousand per unit.
- Optimize commercial integrated circuits in wideband digital synthesizers, and custom high dynamic range Analog/Digital Converters and digital filters into a mixed-signal Analog Signal Integrated Circuits using the latest processes in SiGe and 90nm CMOS.
- Integrate a modem, quad-band antenna, and Ultra-Wide Band (UWB) antenna and transmitter with commercial interface to create an embedded processing unit.

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	FY 2006	FY 2007	FY 2008	FY 2009
MEMS Electronic & Photonic Integrated Circuits in Silicon	10.000	5.000	0.000	0.000

(U) This program will provide new systems capabilities for integrated RF microsystems by developing material and device processing technologies for integrating microelectromechanical RF structures (MEMS) with integrated RF/microwave/millimeterwave (MMWAVE) electronics to form reconfigurable, multi-functional active RF surfaces. The integration of massive numbers of miniaturized MEMS structures with advanced control and RF processing will enable fully programmable metallic and active RF processing surfaces, which will be capable of rapid reconfiguration under electronic control to adapt their resonant and out-of-band characteristics, creating new classes of components that can rapidly and efficiently span electromagnetic bands with high signal-to-noise ratio and minimal losses. These highly integrated active RF elements will consist of efficient, low loss, low power, agile transceivers with high speed digital RF memories, precision analog/mixed signal circuits, and MEMS sensors and structures for actively reconfiguring the resonant structures and devices. This technology will transition through the electronics industry performers and eventual DoD systems utilizing this integrated microelectromechanical RF technology.

(U) Program Plans:

- Develop and demonstrate fabrication technologies for critical high performance electronics and micromachined components with very high quality factors and high performance radio-frequency characteristics compatible with integration into active radio frequency surfaces.
- Develop and demonstrate chip and device-scale electromagnetic isolation approaches.
- Complete development of scaled fabrication process for reducing power and insertion loss of integrated radio-frequency components.
- Complete measurements of radio-frequency parameters of integrated radio-frequency components and perform de-embedding analysis.
- Demonstrate integration technologies that result in the ability to combine high speed analog/mixed signal electronics with digital control devices and with micromachined devices to form active surfaces for agile radio-frequency microsystems.
- Develop control algorithms for controlling the active electronics and micromachined components across wide dynamic range and bandwidth for active radio-frequency surface applications.
- Complete far-field and power measurements of fully programmable radio-frequency active surface microsystem.

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	FY 2006	FY 2007	FY 2008	FY 2009
Airplane on a Chip (AOC) - Chip Scale Avionics	0.000	0.000	3.000	5.000

(U) The Airplane-on-a-Chip (AOC) program seeks to exploit continued advances in integrated Microsystems technology to remake the stovepipe/legacy avionics architecture present in modern aircraft. The fundamental goal of the program is to deliver an avionics system approaching one cubic centimeter in volume and dissipating 10s of milliwatts of power, compared with 10s of cubic centimeters (best case) and 10s of Watts of power in contemporary systems. The program will bring together advances in Chip Scale Atomic Clocks, Navigation Grade Integrated Micro Gyroscopes, 3-Dimensional Electronics, Compressive Sensing, Chip Scale Wavelength Division Multiplexing, and Robust Integrated Power Sources, to name only a few, to revolutionize avionics for the 21st century. It is expected that such advances will revolutionize airframe design and capability by delivering more functionality at lower power in a smaller volume, enabling distributed avionics for enhanced survivability and increase autonomous operation.

(U) Program Plans:

- Develop advanced integrated microsystems technologies for avionics guidance, navigation, and control that exploit progress in Chip Scale Atomic Clocks, Navigation Grade Integrated Micro Gyroscopes, 3-Dimensional Electronics, Compressive Sensing, Chip Scale Wavelength Division Multiplexing, and Robust Integrated Power Sources.
- Deliver an avionics system approaching one cubic centimeter in volume with power dissipation on the order of 10s of milliwatts.

	FY 2006	FY 2007	FY 2008	FY 2009
Nanophotonics for Ultradense On-chip Communications	0.000	5.000	8.500	12.000

(U) The goal of the Nanophotonics for Ultradense On-chip Communications program is to demonstrate nanophotonic technology for (1) access to on-chip ultradense systems and (2) I/O to/from a chip containing such ultradense systems. Technical challenges that must be met include: high precision, low loss nanophotonic circuit fabrication, low cost fabrication methods, high performance nanoscale modulators, detectors, multiplexers and demultiplexers, architecture for addressing ultradense systems, techniques for efficient high capacity/bandwidth I/O of

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data to and from the chip. This technology will transition via industrial performers developing everfaster and more complex processing such as real-time pattern matching, target recognition, image processing and THz class command-and-control networks.

(U) Program Plans:

- Demonstrate high performance, low power active and passive photonics at ~ 1 mm size-scale for on-chip global interconnects for significantly improved processor performance.
- Demonstrate seamless interface between intrachip and ultra dense capacity off-chip communication utilizing nanophotonic components.
- Investigate novel processor architectures enabled by increased interconnect speed and density available from photonics.

	FY 2006	FY 2007	FY 2008	FY 2009
Hemispherical Array Detector for Imaging (HARDI) - Electronic Eye	0.000	5.000	8.000	12.000

(U) The objective of the Hemispherical Array Detector for Imaging (HARDI) program (formerly Electronic Eye) is to exploit the benefits of the hemispherical imaging surface. The basic idea behind the program is that a detector array can be fabricated on a hemispherical substrate using materials such as organic/inorganic semiconductors and that this array can be combined with a single lens to produce a wide field of view, small form factor camera. Organic materials have been shown to have good electronic and optoelectronic properties including light emission and detection. Furthermore, in-plane organic/inorganic transistors can be incorporated for pre-processing of images. This program will transition to eventual DoD systems through a demonstration of an array prototype developed by industrial contractors.

(U) Program Plans:

- Develop high quantum efficiency semiconductor materials for photo-detection in the 400-1900 nm range that can be deposited onto curved surfaces.
- Develop modeling to predict optimum materials and device performance.
- Develop technology to deposit pixel control circuitry onto a curved surface.
- Develop processes to fabricate 20 micron a side pixels on a curved surface with 80% fill factor.

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- Develop methods to integrate read-out circuitry to focal plane on a hemispherical surface.
- Fabricate a 1024 x 1024 pixel focal plane array on a 1 cm radius hemispherical curved surface.
- Evaluate focal plane array architecture with ray tracing programs such as Zemax.

	FY 2006	FY 2007	FY 2008	FY 2009
Day/Night Adaptive Imager	0.000	0.000	3.000	9.000

(U) Low light level imaging has proved its value in providing the individual warfighter with the tactical advantage to see first in crucial night imaging scenarios. With widespread use of low light level technology, a new paradigm in low light level imaging is necessary to maintain these distinct advantages and provide new capability beyond current imaging technology. The new approach is the noiseless detection and processing of individual photon events, which leverages the benefits of solid state imaging and takes advantage of three dimensional signal processing architecture at the detector. By detecting an image formed from individual photon events without the addition of excess noise, the image can be processed and manipulated to provide the user image information not possible with current sensors.

(U) Programs Plans:

- Develop ultra wide dynamic range imaging sensors that count individual photon events and also operate in high light level.
- Reduce dark counts for room temperature operation.
- Demonstrate integrated functions, such as day / night imaging with covert signal detection.

	FY 2006	FY 2007	FY 2008	FY 2009
Miniature, Room Temperature, Ultra-sensitive Magnetic Sensor	0.000	0.000	3.500	10.500

(U) The goal of this effort is to develop a micron scale, room temperature magnetic sensor with detection sensitivity at least comparable to that of a Superconducting Quantum Interference Device (SQUID). The device would also require low power and be produced with standard micro-

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fabrication processes. Recent work in organic materials that preserve electron spin coherence over tens to hundreds of nanometers and also in atomtronics suggest that room temperature ultra sensitive magnetic sensors are achievable.

(U) Program Plans:

- Determine specific metrics and requirements for applications of ultra-sensitive (sub-pico tesla), room temperature magnetic sensors with performance comparable to that of a SQUID device but without cryogenic operation.
- Fabricate and optimize device architectures with half-metal/organic semiconductor/half-metal sandwich structures at sub-mm scales and evaluate magnetic field sensitivity.
- Engineer organic semiconductors for optimum spin injection, spin coherence length, spin-orbit and hyperfine interaction.
- Develop optimum processes for device fabrication to enhance magneto-resistance and reduce noise in presence of earth's magnetic field.
- Determine device performance as a function of temperature and frequency.
- Develop theoretical modeling and simulation to evaluate potential to achieve sensitivity comparable to that of SQUID devices without cryogenic operation.
- Fabricate multiple devices to determine yield, stability, and robustness.

	FY 2006	FY 2007	FY 2008	FY 2009
Contiguous Multi-Mega-pixel Infrared Imaging Arrays	0.000	0.000	3.000	7.000

(U) This program will address the development of large arrays for persistent surveillance with the objective of developing technology for multi-mega-pixel pixel arrays with integral signal and image processing. Since contiguous coverage over large areas is essential, approaches will be developed to construct extremely large array assemblies from smaller arrays without loss of lines at the intersection between arrays. A new array architecture will be designed to integrate electronic overhead functions, such as synchronization clocks, power bias lines and ground connections in a three dimensional structure directly under the active pixel array. This design leverages and extends the emerging three dimensional signal processing technology and establishes a technology base for large contiguous array assemblies, not possible with current

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infrared arrays. Approaches also will be developed for the assembly of multiple infrared arrays on non-planar surfaces in order to realize practical optical designs for large arrays.

(U) Program Plans:

- Develop approaches for contiguous butting of large infrared arrays without line loss at array intersection.
- Demonstrate large multi-color arrays with integral data pre-screening to highlight potential targets and areas of interest.

	FY 2006	FY 2007	FY 2008	FY 2009
High Resolution Short Wave Infrared	0.000	0.000	3.000	10.000

(U) This program will address emerging material growth and deposition technology with the potential to produce extremely high resolution, high density short wave detector arrays. Growth approaches to be investigated include infrared quantum dots, which can be deposited directly from a solution, molecular beam epitaxy, and epitaxial growth onto selected areas of the silicon read-out. The growth techniques must be optimized to produce films with high optical absorption, and uniform film characteristics consistent with deposition over large areas. Electrical contact to small size detector elements also will be addressed. Approaches must be developed to form the electrical contact between small area detectors and input to low noise preamplifiers on the silicon substrates.

(U) Program Plans:

- Develop material growth and array processing for extremely high-resolution short wave infrared with pixel size on the order of the wavelength.
- Develop new detector approaches for high pixel density with passivation processes to control surface leakage, which will dominate small detectors.
- Demonstrate test structures with detector size approaching 2 microns and show contact method to small pixel structure.

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	FY 2006	FY 2007	FY 2008	FY 2009
Control of Optical Properties of Infrared Semiconductors	0.000	0.000	3.250	10.000

(U) This program seeks to electronically control the optical emission from infrared semiconductor material in infrared material and devices with pay-off in several new areas important to Defense Systems. The equilibrium level of electronic charge carriers in a semiconductor material can be controlled by the applied bias, altering optical emission at the surface. In a light emitting diode, electronic injection of excess charge into a semiconductor stimulates radiation emission. Analogously, the extraction of charge carriers suppresses radiation emitted from the sample. In the infrared spectral region, radiation emitted from a semiconductor defines the apparent temperature of the material. Control of the apparent temperature of infrared material has direct application in radiation shielding for room temperature detectors, covert communications and marking targets in the infrared. Radiation shielding in room temperature imager has the potential to increase sensitivity five to ten times expanding the application base of room temperature infrared imagers.

(U) Program Plans:

- Demonstrate detection of modulated signal with zero average using existing 3-5um NL material.
- Reduce Long-Wave Infrared (LWIR) dark current and material doping by X10.
- Investigate growth of LWIR material on silicon substrates for larger area, lower cost and longer range.

	FY 2006	FY 2007	FY 2008	FY 2009
Micro-Systems Thermal Management	0.000	0.000	3.750	11.000

(U) The objective of the Micro-Systems Thermal Management Program is to develop a new class of devices using a concurrent design approach to develop isothermal chips with the requisite electrical characteristics and thermal management designed into the device. The goal is to increase the heat dissipation rate allowing the design of high power conversion and motor drive systems to be reduced by approximately 1/3. This will significantly reduce the system size and complexity required to increase warfighting capability in smaller, lighter, more reliable and affordable radar power conditioning systems, power conversion and motor drives and avionics.

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- (U) Program Plans:
- Synthesize nano-scaled materials with the requisite electronic and thermal characteristics.
 - Integrate devices into a power module with a 1/3 reduction in design complexity.
 - Increase the rate of heat dissipation from 100W/cm² to 10kW/cm².

	FY 2006	FY 2007	FY 2008	FY 2009
Electronic Miniaturization	5.100	2.800	0.000	0.000

- (U) Program Plans:
- Develop novel techniques for miniaturization of electronic components.

	FY 2006	FY 2007	FY 2008	FY 2009
Small Scale Systems Packaging	1.000	0.000	0.000	0.000

- (U) Program Plans:
- Developed new approaches for packaging of small electronic components.

	FY 2006	FY 2007	FY 2008	FY 2009
Advanced Lithography Fabrication Processing	2.550	0.000	0.000	0.000

- (U) Program Plans:
- Developed new fabrication processing technology in lithography systems.

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	FY 2006	FY 2007	FY 2008	FY 2009
Enabling Ubiquitous Computing through Nanoscale Ultra-Low Power Electronics	0.000	1.000	0.000	0.000

- (U) Program Plans:
- Develop nanoscale low power electronics for defense applications.

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

- Not Applicable.

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