Exhibit R-2, **RDT&E Budget Item Justification:** PB 2011 Defense Advanced Research Projects Agency	**DATE:** February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 3: *Advanced Technology Development (ATD)*	**R-1 ITEM NOMENCLATURE** PE 0603739E: *ADVANCED ELECTRONICS TECHNOLOGIES*

COST ($ in Millions)	FY 2009 Actual	FY 2010 Estimate	FY 2011 Base Estimate	FY 2011 OCO Estimate	FY 2011 Total Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
Total Program Element	192.686	194.094	197.098	0.000	197.098	151.274	157.386	150.143	149.334	Continuing	Continuing
MT-07: *CENTERS OF EXCELLENCE*	7.000	7.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Continuing	Continuing
MT-12: *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	63.439	77.963	64.496	0.000	64.496	44.150	50.390	50.037	50.095	Continuing	Continuing
MT-15: *MIXED TECHNOLOGY INTEGRATION*	122.247	109.131	132.602	0.000	132.602	107.124	106.996	100.106	99.239	Continuing	Continuing

A. Mission Description and Budget Item Justification

(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 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

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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 provided funding to finance the demonstration, training and deployment of advanced manufacturing technology at Marshall University and the MilTech Extension program.

B. Program Change Summary ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
Previous President's Budget	199.504	205.912	0.000	0.000	0.000
Current President's Budget	192.686	194.094	197.098	0.000	197.098
Total Adjustments	-6.818	-11.818	197.098	0.000	197.098
• Congressional General Reductions		-0.813			
• Congressional Directed Reductions		-33.005			
• Congressional Rescissions	-3.798	0.000			
• Congressional Adds		7.000			
• Congressional Directed Transfers		0.000			
• Reprogrammings	2.585	0.000			
• SBIR/STTR Transfer	-5.605	0.000			
• Congressional Restoration for New Starts	0.000	15.000	0.000	0.000	0.000
• TotalOtherAdjustments	0.000	0.000	197.098	0.000	197.098

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2009	FY 2010
Project: MT-07: *CENTERS OF EXCELLENCE*		
Congressional Add: *Advanced Flexible Manufacturing*	7.000	7.000
Congressional Add Subtotals for Project: MT-07	7.000	7.000
Project: MT-15: *MIXED TECHNOLOGY INTEGRATION*		
Congressional Add: *Center for Autonomous Solar Power*	4.000	0.000
Congressional Add: *Hybrid Power Generation System*	1.200	0.000
Congressional Add: *Ultra Low Power Electronics for Special Purpose Computers/Ubiquitous Computing*	1.600	0.000

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Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2009	FY 2010
Congressional Add Subtotals for Project: MT-15	6.800	0.000
Congressional Add Totals for all Projects	13.800	7.000

Change Summary Explanation

FY 2009

Decrease reflects SBIR/STTR transfer and Section 8042 rescission of the FY 2010 Appropriations Act offset by internal below threshold reprogramming.

FY 2010

Decrease reflects reductions for the Section 8097 Economic Assumption, execution delays and FY 2010 new starts offset by the FY 2010 Congressional Restoration for New Starts.

FY 2011

Not Applicable

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency	**DATE:** February 2010

APPROPRIATION/BUDGET ACTIVITY	**R-1 ITEM NOMENCLATURE**	**PROJECT**
0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 3: *Advanced Technology Development (ATD)*	PE 0603739E: *ADVANCED ELECTRONICS TECHNOLOGIES*	MT-07: *CENTERS OF EXCELLENCE*

COST ($ in Millions)	FY 2009 Actual	FY 2010 Estimate	FY 2011 Base Estimate	FY 2011 OCO Estimate	FY 2011 Total Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
MT-07: *CENTERS OF EXCELLENCE*	7.000	7.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Continuing	Continuing

A. Mission Description and Budget Item Justification

(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.

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010
Congressional Add: Advanced Flexible Manufacturing *FY 2009 Accomplishments:* - Assessed the Institute for Advanced Flexible Manufacturing's performance and worked toward transitioning from DoD to state/private support. *FY 2010 Plans:* - Continue to Assess the Institute for Advanced Flexible Manufacturing's performance and work toward transitioning from DoD to state/private support.	7.000	7.000
Congressional Adds Subtotals	7.000	7.000

C. Other Program Funding Summary ($ in Millions)

N/A

D. Acquisition Strategy

N/A

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E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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COST ($ in Millions)	FY 2009 Actual	FY 2010 Estimate	FY 2011 Base Estimate	FY 2011 OCO Estimate	FY 2011 Total Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
MT-12: *MEMS AND INTEGRATED MICROSYSTEMS TECHNOLOGY*	63.439	77.963	64.496	0.000	64.496	44.150	50.390	50.037	50.095	Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) The MicroElectroMechanical Systems (MEMS) and Integrated Microsystems Technology 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 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) chemical reactions on chip; 5) electromechanical signal processing; 6) analytical instruments; and 7) thermal management.

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
Harsh Environment Robust Micromechanical Technology (HERMIT)	6.495	3.600	0.000	0.000	0.000
(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) while maintaining					

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
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, two are of the most interest: 1) wafer-level encapsulation or packaging strategies based on MicroElectroMechanical systems (MEMS) technology that isolates a micromechanical device from its surroundings while maintaining a desired environment via passive or active control; and 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. *FY 2009 Accomplishments:* - Demonstrated micromechanical devices (e.g., RF switches, vibrating resonators) fully integrated together with environment isolating measures (including circuits, if any) that maintain unprecedented performance, stability, and reliability, even under harsh environments. - Demonstrated high yield MEMS RF switching component technologies that result in test devices that can operate for at least 100 billion switching cycles. Yield goals were to attain a 95% confidence that 99% of tested devices met 100 billion cycles. - Implemented parallel measurement set-up to increase test throughput. - Initiated efforts for demonstrating the performance of RF switches in relevant radar applications.					

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2010 Plans: - Demonstrate hermetic packaging technology for advanced MEMS inertial gyroscopes and accelerometers.					
MEMS Exchange (U) The MEMS Exchange 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 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. *FY 2009 Accomplishments:* - Inserted MEMS technology into three DoD applications using MEMS Exchange as the fabrication vehicle. *FY 2010 Plans:* - Implement new state-of-the-art technical unit process capabilities to achieve greater effectiveness for creating MEMS devices, including electron-beam lithography, mixed transistor and MEMS process modules, and general purpose MEMS hermetic packaging. - Initiate new quality control efforts to achieve higher reliability in manufacturing. *FY 2011 Base Plans:* - Optimize process cost efficiencies by increased marketing of MEMS Exchange capability.	2.467	2.376	1.600	0.000	1.600

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
- Improve self-sufficiency by providing a higher value to program users by improved yield and lower manufacturing costs.					
Low Power Micro Cryogenic Coolers (MCC) (U) The Low Power Micro Cryogenic Coolers (MCC) 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. Additionally, this program will develop a high performance chip-scale micropump for efficient fluid distribution within various microsystems. 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, which will incorporate elements of the technology in current and future weapon system designs. *FY 2009 Accomplishments:* - Integrated micro cooler components together with sufficiently isolated devices to-be-cooled to yield a single chip system consuming very little power. - Developed methods to increase compression ratio and pump speeds to MEMS scales. - Decreased size of on-chip vacuum pumps. *FY 2010 Plans:* - Improve MEMS-derived thermal isolation microstructures. - Develop improved thermoelectric materials for integration with existing and future MEMS. - Demonstrate turbomolecular pumping.	8.711	8.223	6.533	0.000	6.533

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
- Demonstrate micromechanical vacuum on a chip with less than 1 Torr operating pressure. *FY 2011 Base Plans:* - Develop MEMS-based analytical instruments of <10^-6 Torr with a sampling flow rate with on-chip vacuum conditions.					
Microsystem Integrated Navigation Technology (MINT) (U) The Microsystem Integrated Navigation Technology (MINT) program is developing technology for precision inertial navigation coupled with micro navigation aiding sensors. The MINT 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. Program transition will occur through industrial performers into future DoD platforms. *FY 2009 Accomplishments:* - Reduced power and volume requirements. - Developed technologies to harvest power through energy scavenging. *FY 2010 Plans:* - Develop and demonstrate micro-fabrication technologies for creating new classes of MEMS navigation instruments that can be used for achieving high accuracy, GPS free navigation using zero-velocity updating. *FY 2011 Base Plans:* - Initiate measurements and testing of initial MINT navigation prototypes at DoD laboratories to confirm navigation properties and accuracies.	5.991	6.687	6.549	0.000	6.549
Integrated Primary Atomic Clock (IMPACT)	7.970	6.916	7.796	0.000	7.796

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
(U) The Integrated Primary Atomic Clock (IMPACT) program will extend the accuracy of Chip Scale Atomic Clock (CSAC) 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. *FY 2009 Accomplishments:* - Determined pressure measurement in presence of high magnetic field with MEMS pressure sensors. - Identified retrace drifts and reduced zero aging of atomic frequency. *FY 2010 Plans:* - Initiate technology development efforts for demonstrating a complete physics package for an advanced miniaturizable atomic clock that can interrogate gaseous atoms and does not suffer from light shifts and buffer gas shifts that usually limit the use of hyperfine transition frequencies for applications to clocks. *FY 2011 Base Plans:* - Initiate fabrication technologies to develop an advanced approach that will reduce size, weight and power of physics package to enable dramatic reductions in the size and power of the physics package along with the entire integrated timing assembly.					
Nano-Electro-Mechanical Computers (NEMS) (U) The goal of the Nano-Electro-Mechanical Computers (NEMS) program is to develop nanoscale mechanical switches and gain elements integrated intimately with complementary metal-oxide	3.916	6.918	6.829	0.000	6.829

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
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 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. Mechanical power supplies and mechanical vibrating clocks could facilitate production of electronics that are less susceptible to electromagnetic pulse attacks. Integrating nanomechanical elements in direct bandgap materials will circumvent problems of gate oxide stability, allowing fast logic with optics functionality. This program will transition into DoD systems via industrial program performers. *FY 2009 Accomplishments:* - Developed NEMS switches in direct bandgap materials to enable optical functionality with switches. *FY 2010 Plans:* - Demonstrate NEMS devices and technologies for microcontroller building blocks - adders, counters, memories, that can operate at very high temperatures. *FY 2011 Base Plans:* - Demonstrate capability to produce analog mechanical components such as operational amplifiers that can operate with 100X lower input noise than conventional approaches.					
Information Tethered Microscale Autonomous Rotary Stages (ITMARS) (U) Early MEMS work had demonstrated many ways of realizing rotating micromotors, and in fact had been the source of major popular interest in the field of micromachines. However, the unique capability to precisely rotate micromachined structures in a controllable manner has been under-utilized in MEMS systems. Although the use in micromotors for optical and mechanical switches has been demonstrated, most applications passively use the structures fabricated into the rotary stage. To date there is no technology able to transmit power and signals to these tiny stages from the substrate on	2.907	4.452	4.993	0.000	4.993

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
which they are rotating. This program will explore ways at pushing the envelope by engineering ways of coupling power and signals to a rotating MEMS stage, and measuring its position with much higher accuracy then possible at the macroscale. With this capability, arrays of rotating 100-1000 micron diameter stages could carry various sensors that can be aimed at any azimuth and inclination, and can be rotated 360 degrees for cancelling angle dependent biases. Examples of sensors that might utilize this capability include microphones, antennas, radiation sensors, etc. Although many of these sensors exist, by adding the rotating stage functionality without increase in sensor/system size, weight, and power, one can really see the benefit of integrating MEMS with traditional sensors. The program will transition via industry performers. *FY 2009 Accomplishments:* - Initiated efforts to implement power and information to microscale rotating stages, for various applications. *FY 2010 Plans:* - Develop prototype applications. - Reduce bias levels in sensors, increase directivity in directional sensors, and achieve mechanical phased arrays. *FY 2011 Base Plans:* - Integrate micro rotating stages with integrated circuits (ICs) to achieve 1-cubic centimeter (cc) microsystem.					
Chip-Scale Micro Gas Analyzers (U) The Chip-Scale Micro Gas Analyzers program is utilizing the latest microelectromechanical systems (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/	9.553	6.433	7.761	0.000	7.761

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
biological agents. The use of MEMS technology will also increase analysis speed and made 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. This program will also develop micro-resonators that accept and isolate narrow channels of the radio spectrum. This research would enable communication receivers that operate under any communication standard around the world. The Chip-Scale Gas Analyzers program is transitioning 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). *FY 2009 Accomplishments:* - Demonstrated advanced methods for making micromechanical sensor elements species sensitive (e.g.,combinations of absorption spectroscopy and resonators coated with species-and-light sensitive films). - Implemented fully functional, MEMS-enabled gas separation analyzers with power consumptions small enough for autonomous, remote operation and control electronics integrated directly. - Focused on single channel at 3 GHz. - Initiated effort at 60 channels with 30 KHz spacing. *FY 2010 Plans:* - Fabricate single nanoresonator with Quality Factor Q > 100,000 and operating frequency greater than 3 GHz. - Improve rejection of unwanted signals while minimizing impedance. - Match resonators to analog-to-digital converters.					

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2011 Base Plans: - Continue to develop resonators with high quality (>30,000) at high frequencies.					
Thermal Management Technologies (TMT) (U) The goal of the Thermal Management Technologies program is to explore and optimize new nanostructured materials and other recent advances for use in thermal management systems. Innovative research is underway to go beyond evolutionary thermal management systems. Modem, high-performance heat spreaders, which use two-phase cooling, are being developed to replace the copper alloy spreaders in conventional systems. Enhancing air-cooled exchangers by reducing the thermal resistance through the heat sink to the ambient, increasing convection through the system, improving heat sink fin thermal conductivity, optimizing and/or redesigning the complimentary heat sink blower, and increasing the overall system (heat sink and blower) coefficient of performance is another thrust of this program. Another element of this effort is focused on novel materials and structures that can provide significant reductions in the thermal resistance of the thermal interface layer between the backside of an electronic device and the next layer of the package, which might be a spreader or a heat sink. The Thermal Management Technologies program is an aggregation of: Thermal Ground Plane (TGP), Microtechnologies for AirCooled Exchangers (MACE), Nano Thermal Interfaces (NTI) and Active Cooling Modules (ACM) technology research. Technology will be inserted through DoD industrial firms into future DoD systems. *FY 2009 Accomplishments:* - Demonstrated the performance benefits of an integrated high-performance thermal materials and substrates through refining of wick materials and tuning the composition of the casing. - Fabricated and tested a 'single-fin' heat sink device. - Performed experiments to verify properties and performance.	15.429	32.358	22.435	0.000	22.435

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2010 Plans: - Investigate active cooling of electronic devices using techniques such as thermoelectric coolers, sterling engines, etc. - Demonstrate a full-performance high-thermal conductivity substrate with enhanced thermal conductivity, hermeticity, and lifetime in a scaled-up 20 cm x 10 cm x <1mm sample. - Scale up prototype air-cooled exchangers to a large, full-format heat sink. - Develop and demonstrate full-sized heat sink using air-cooled exchanger technologies. *FY 2011 Base Plans:* - Deliver fifty sample thermal conductivity substrate components for testing and insertion into DoD systems. - Design and build modules with all interfaces that demonstrate ACM benefits. - Reduce junction temperature for electronic devices. - Further increase electronic device power. - Increase device reliability. - Identify DoD insertion opportunities, revise testing and reliability activities to meet insertions, and provide testing samples. - Modify parameters of specific DoD insertions.					
Accomplishments/Planned Programs Subtotals	63.439	77.963	64.496	0.000	64.496

C. Other Program Funding Summary ($ in Millions)

N/A

D. Acquisition Strategy

N/A

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E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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COST ($ in Millions)	FY 2009 Actual	FY 2010 Estimate	FY 2011 Base Estimate	FY 2011 OCO Estimate	FY 2011 Total Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
MT-15: *MIXED TECHNOLOGY INTEGRATION*	122.247	109.131	132.602	0.000	132.602	107.124	106.996	100.106	99.239	Continuing	Continuing

A. Mission Description and Budget Item Justification

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

B. Accomplishments/Planned Program ($ in Millions)

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
Adaptive Photonic Phased Locked Elements (APPLE) Phase II	9.521	11.182	20.000	0.000	20.000
(U) The Adaptive Photonic Phase-Locked Elements (APPLE) Phase II program will develop ultra-compact, electronically-steerable, high power optical phased arrays, with each array element driven ultimately by a 3 kW fiber laser amplifier being developed in the Revolution in Fiber Lasers (RIFL) program. Each array element will contain an adaptive optics system to correct for the beam spreading effects of atmospheric turbulence and will have a clear aperture dimension of 2.5 cm to allow compensation for even the strongest atmospheric turbulence encountered in ground-to-air, air-to-air, and ground-to-space applications with only tip/tilt control. This conformal optical phased array technology is scalable in both power and total aperture size by adding additional elements to the array. The high power optical phased array technology being developed in this program will serve a broad spectrum of applications including laser communications, broad-area search and track, Identification of Friend or Foe (IFF), missile seeker negation, and at high power, surgical kill of strategic and tactical targets with minimal collateral damage. Technology will transition to Industry. *FY 2009 Accomplishments:* - Demonstrated high power combined output of multiple (7) small individual apertures. *FY 2010 Plans:* - Demonstrate atmospheric compensation in the real atmosphere at low powers. - Develop a fiber-array testbed with twenty-four phase-locked channels for analysis of potential scaling limitations on fiber-array high energy laser systems. *FY 2011 Base Plans:* - Design 7-element optical phased array with array elements suitable for 1 kW coherently combinable fiber laser amplifiers. - Design experiments to determine the maximum number of array elements that can be coherently combined in a target-in-the-loop configuration as a function of noise in each of the array channels.					
Visible/Short Wave IR - Photon Counting	3.054	2.083	0.000	0.000	0.000

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
(U) The Visible/Short Wave IR - Photon Counting 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. *FY 2009 Accomplishments:* - Demonstrated single photon counting devices for ultra low noise imaging. - Designed and built prototype real-time processor. *FY 2010 Plans:* - Demonstrate real-time processor and interface with an existing photon counting camera.					
Dual-Mode Detector Ensemble (DUDE) (U) The Dual-Mode Detector Ensemble (DUDE) demonstrates the integration of an uncooled long wave infrared sensor (LWIR) (8-12 microns) with a sensor that operates in the Visible/Near Infrared/SWIR (VNS) (0.4-1.6 microns) spectral range. The integration of this combined day/night focal plane with the broad spectral band flat-format optics will realize a compact day/night rifle sight system. The combined sensor will provide the soldier with the ability to utilize aiming lights registered with the thermal image, see through windows with the reflected light sensors, identify people at night, and see targets on the battlefield designated from other sources, while reducing the logistics burden and weight they have to carry. These together would be a major paradigm shift in the technology. The demonstration array will be a large format long wave infrared array operating at room temperature with four reflected light pixels	5.772	9.834	5.543	0.000	5.543

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
for each long wave pixel, and evaluated for rifle sight applications. The technology will transition via industry upon successful completion of the program. *FY 2009 Accomplishments:* - Reduced dark counts for room temperature operation. - Demonstrated integrated functions, such as day/night imaging with covert signal detection. *FY 2010 Plans:* - Build 640x512 infrared array integrated with a Visible/Near-IR/Short-wave IR (VNS) array. - Demonstrate VNS array with the pixels meeting dark current of 50 na/cm^2 at 10 degrees C. - Demonstrate aiming lights co-registered with the infrared array. *FY 2011 Base Plans:* - Build 640x512 long wave infrared array with 20 micrometer unit cell, with four VNS pixels per unit cell. - Demonstrate VNS array with the pixels meeting dark current of 20 na/cm^2 at 10 degrees C. - Demonstrate man-recognition range at 1 km.					
Hemispherical Array Detector for Imaging (HARDI) (U) The objective of the Hemispherical Array Detector for Imaging (HARDI) program 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.	2.109	2.328	2.754	0.000	2.754

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2009 Accomplishments: - Developed improved materials for Visable-Near IR and Shortwave IR. - Demonstrated a curved focal plane array. *FY 2010 Plans:* - Develop novel photodetector materials for the spectral range 400-1900 nanometers (nm). - Demonstrate a 16,000 pixel array on a 2.5 cm radius hemispherical substrate. - Explore manufacturing techniques amenable to producing hemispherical array detectors with high reproducibility. *FY 2011 Base Plans:* - Demonstrate a prototype 1 megapixel, 1 cm radius hemispherical focal plane array for the spectral range of 400-1900 nm. - Demonstrate a prototype f/1.4 camera with a 120 degree field of view with high reliability.					
Photon Trap Structures for Quantum Advanced Detectors (P-SQUAD) (U) The objective of Photon Trap Structures for Quantum Advanced Detectors (P-SQUAD) is to develop technologies for fabrication of multi-stacked and multi-functional nano-pillar materials structures for various new and improved devices. The main objective is to develop a process technology that allows fabrication of nano-pillar stacked architectures of at least three different semiconductor materials for multi-spectral infrared (IR) detector technology. This technology will transition via the program's industrial performers. *FY 2009 Accomplishments:* - Fabricated 16 x 16 detector arrays using nano-pillar arrays. - Validated P-SQUAD structure design characteristics using experimental and theoretical models.	6.061	12.520	14.668	0.000	14.668

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2010 Plans: - Demonstrate a 640 x 480 array that is fully integrated with readout processor. - Design and validate P-SQUAD integrated array. *FY 2011 Base Plans:* - Demonstrate an integrated 640 x 480 imaging camera prototype using P-SQUAD devices and fully characterize. - Validate PT-SQUAD integrated array design. - Deliver four fully characterized 640 x 480 focal plane arrays.					
Nyquist-Limited Infrared Detectors (NIRD) (U) The Nyquist-Limited Infrared Detectors (NIRD) program develops high density, long-wave infrared (LWIR) arrays and signal processing to improve capability to image through scattering media such as dust and sand, known as brownout, fog, snow storms, and to enhance situational awareness needed for aircraft navigation. The LWIR provides advantages in imaging through the dust clouds created in helicopter landing especially in desert areas. This obscurant penetration capability of LWIR imaging can be significantly improved when the pixel size is reduced to preserve high frequency information, while at the same time, a practical size optical aperture is maintained with approximately F/1 optics. The obscurant penetration capability of the LWIR focal plane array (FPA) can be further enhanced with signal and imaging processing. The low frequency pedestal in the image caused by the obscurant must be reduced to increase image contrast and the effective dynamic range. The small pixel FPA presents unique challenges in detector design and fabrication and in the interconnection of the detector array to the read-out integrated circuit (ROIC). The origin of noise currents in the detector must be understood and characterized, especially the role of surface currents in the small pixel devices. The method of interconnection must be compatible with large arrays of small pixel elements, achieve a low contact resistance, and reliably interconnect at each pixel across the array. This program will transition via industry upon successful completion.	4.218	10.372	7.724	0.000	7.724

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2009 Accomplishments: - Developed new detector approaches for high pixel density with passivation processes to control surface leakage, which will dominate small detectors. - Demonstrated test structures with detector size approaching two microns and illustrated contact method to small pixel structure. - Conducted feasibility study incorporating the results from the static runway measurements, outside data collection sources, and dynamic flight tests. - Developed requirements to support the development of a high resolution sensor pertinent to limited visibility flight operations. *FY 2010 Plans:* - Demonstrate LWIR detectors, with a size of 5 micrometers, operating at 80K with dark current less than 0.5ma/cm^2. - Achieve 10 x 10 LWIR array with 5 micrometer pixels interconnected to silicon read-out with interconnect resistance less than 5 ohm. *FY 2011 Base Plans:* - Achieve 256x256 array with 5 micrometer pixels showing 90% of pixels at dark current goal. - Perform high-density interconnection between detector and read-out circuit with less than 10% change in interconnect resistance after 1000 cycles.					
Advanced Photonic Switch (APS) (U) The objective of the Advanced Photonic Switch (APS) program is to develop a technology for creating on-chip, photonic switching devices which can be fabricated in a silicon-compatible process. Most high performance photonic switching devices are fabricated with compound semiconductors, but silicon manufacturing technologies now offer potential advantages due to the great precision being driven by commercial mainstream markets for microelectronics. This program is pursuing advanced technologies that will take full advantage of those commercial capabilities but will exploit them to	1.380	5.468	3.367	0.000	3.367

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
produce photonic devices that maximize switching speed, minimize device power dissipation and transmission losses, small area, and decreased sensitivity to ambient temperature variations. The photonic switches developed in this program will be spectrally broad-band, capable of simultaneously switching multiple, high bit-rate wavelength channels, and scalable to complex port switches. The switching devices developed in APS will benefit low power, high bandwidth, low latency, photonic communications networks, thereby benefiting a broad array of U.S. Department of Defense (DoD) problems and the larger U.S. National interests in network-based activities. APS will transition to industry. *FY 2009 Accomplishments:* - Completed fabrication of prototype Number of Bits per Second (NOBS) devices to create a 2x2 array. - Designed, fabricated, and tested silicon complementary metal-oxide semiconductor (CMOS) driver circuits that can be integrated with NOBS. *FY 2010 Plans:* - Enhance APS fabrication technologies and design approaches to improve the NOBS devices and integrated assemblies. *FY 2011 Base Plans:* - Develop and implement new design and fabrication technologies for improving the performance of the NOBS devices and integrated assemblies into switches.					
COmpact Ultra-stable Gyro for Absolute Reference (COUGAR) (U) The COmpact Ultra-stable Gyro for Absolute Reference (COUGAR) program goal is to realize the fundamental performance potential of the resonant fiber optic gyro (RFOG) in combination with bandgap optical fiber (BGOF), ultra-stable compact lasers, phase conjugate elements (PCEs), and silicon optical benches: a compact ultra-stable gyro for absolute reference applications. The COUGAR	5.761	10.004	12.716	0.000	12.716

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
gyro will have a practical and typical size (~ 4 inch diameter) featuring bias stability and sensitivity (or angle random walk), which is more than 100 times better than state-of-the-art gyroscopes. This program will transition via industry. *FY 2009 Accomplishments:* - Developed purely single-polarization low-loss, low glass-content BGOF. - Demonstrated compact narrow line-width single-frequency laser technology with ultra-low jitter and the capability of extremely linear frequency scanning. - Developed resonator-ready (low-loss) PCEs for mitigating residual non-linear Kerr Effect errors and relaxing tolerances on laser intensity stabilization requirements. - Developed silicon optical bench technology for optical ruggedization and a path toward a compact and affordable gyroscope. *FY 2010 Plans:* - Initiate development of optical bench interface technology for the air-to-bandgap fiber to then be exploited for a gyroscope with reasonable bias performance levels and consistent with military needs. *FY 2011 Base Plans:* - Demonstrate full gyroscope with integrated electronics and performance exceeding 10 micro-degrees/hr drift.					
Photonic-enabled Simultaneous Transmit and Receive (P-STAR) (U) Information operation missions on multiple military platforms depend on the ability to transmit and receive radio frequency (RF) signals, simultaneously, from a single aperture. This program will develop transmit/receive modules with high transmit-to-receive isolation and low receive noise figures, over a multi-octave bandwidth, to greatly improve situational awareness of the RF environment, and enable greater control over the information domain. Additionally, the program will develop ultra-wideband (0.1 to 20 Gigahertz (GHz)) photonic components (Photodetectors & Modulators) to significantly enhanced	5.871	7.235	9.512	0.000	9.512

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
efficiency for applications in antenna Transmit/Receive (T/R) modules. Furthermore, this program will help stem the proliferation of "mission-specific" antennas by providing an ultra-wide bandwidth antenna that can substitute for multiple custom antenna solutions. It is expected that such components would have a significant impact on wideband, multi-functional, multi-beam, Active Electronically Steerable Array antennas by developing modules and detectors that are independently optimized for T/R applications. In addition to the increased functionality, the improved noise figure of the P-STAR technology will increase stand-off ranges and provide improved indications and warning. The program will transition via its industrial performers. *FY 2009 Accomplishments:* - Fabricated and demonstrated a STAR module which exhibits high T/R isolation over a multi-octave frequency range. - Initiated development of transmit optimized electro-optical transducers and photoreceivers, nominally operating in the 1550 nm band, for operation in the 0.1 to 20 GHz frequency range. *FY 2010 Plans:* - Develop and demonstrate low loss lithium niobate optical modulators, which exhibit low switching voltages and incorporate a long effective length for achieving high T/R isolation. - Develop and demonstrate a power amplifier that when connected to the electro-optic modulator and incorporated into the T/R module package, enables the transmit power goal over a multi-octave frequency range. - Enhance third-order intercept point (OIP3) of the Transmit link to +65 decibels (dB) relative to a milliwatt of power (dBm). - Enhance gain of the Receive link to 35 dB. *FY 2011 Base Plans:* - Enhance output power of the Transmit link to 15 Watts. - Enhance Noise Figure of the Receive link to 3 dB and OIP3 to +43 dBm.					

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
Gratings of Regular Arrays and Trim Exposures (GRATE)	2.585	12.000	13.490	0.000	13.490

(U) The Gratings of Regular Arrays and Trim Exposures (GRATE) program will develop revolutionary circuit design methodologies combined with hybrid lithography tools to enable cost-effective low volume nanofabrication for DoD applications. Moore’s law has driven the silicon industry for several decades with the minimum feature size on an integrated circuit (IC) reduced to 45 nm for today’s commercial products. Due to challenging patterning requirements and complex circuit designs, costs of lithography tools and masks have become unaffordable for low-volume manufacture, i.e., military electronics or application specific integrated circuit (ASICs). Similarly, the circuit design, verification, and testing costs have also grown exponentially further preventing military electronics from using advanced silicon technology nodes. Military electronics capabilities are currently limited by the high cost of nanofabrication. To solve this important problem, DARPA has invested in a variety of maskless patterning technologies including parallel e-beam arrays, parallel scanning probe arrays, and an innovative e-beam lithography tool. This program will develop revolutionary circuit design methodologies coupled with innovative hybrid maskless patterning tools to realize cost-effective nanofabrication for low-volume defense or commercial ASICs. Such an approach can also address the nanofabrication requirements of other low-volume DoD technologies such as photonics and micro-electro-mechanical systems. This program will transition via industry.

FY 2009 Accomplishments:
- Developed 1-D designs and patterning methods.
- Evaluated the efficacy of regular geometry templates for improving lithographic performance for more robust imaging, simplified design/layout process, and increased throughput for maskless lithography methods.
- Verified efficacy of 1-D design approach. Quantitative benefits of 1-D vs traditional 2-D design approach. 2-D to 1-D conversion of legacy design information processing.
- Developed 1-D design enabling process extensions such as “trim/stitch” and “frequency doubling”. 1-D test cell fabrication.
- Studied feasibility of custom grating fabrication tool based on interference lithography.

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2010 Plans: - Develop 1-D fabrication demonstrations. - Develop 1-D standard cell library for digital designs at < 32 nm node. 1-D computer aided design tool development. - 1-D fabrication demos including various circuit elements making use of 1-D specific process extensions. - Demonstrate 1-D circuit patterns using trimmed interference lithography. *FY 2011 Base Plans:* - Demonstrate grating-based design and fabrication, including experimental verification of desired patterns. The demonstration vehicles will be logic/memory "standard cells" and high speed RF devices in state-of-the-art CMOS technologies. - Develop re-usable grating and trim masks, design methodology, process design kits, and software for layout conversion from standard (2D) to grating-based (ID) layout styles. - Demonstrate wafer-scale patterning of gratings, and the customization of these gratings by the "trim/stitch" processes.					
Electromagnetic Pulse Tolerant Microwave Receiver Front End (EMPIRe) (U) The Electromagnetic Pulse Tolerant Microwave Receiver Front End (EMPIRe) program will create a wide bandwidth, tunable RF front end technology that is immune to electromagnetic pulse (EMP) 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. A secondary goal is to effect a significant reduction in detectable radar cross section by eliminating the metallic antenna.	5.879	3.070	2.926	0.000	2.926

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
(U) EMPIRe represents the ultimate solution for protecting wireless communication and radar systems. EMPIRe can find immediate application protecting tactical communication and radar systems, which are highly vulnerable to 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 EMP weapons. *FY 2009 Accomplishments:* - Demonstrated dramatic reduction in RF front-end susceptibility to electromagnetic pulses while maintaining militarily useful system. *FY 2010 Plans:* - Design and simulate microwave receiver front-end and model high power microwave exposure; predict robustness limits based on microwave power handling capability. - Fabricate front-end and test RF performance. - Experimentally validate power handling capability. *FY 2011 Base Plans:* - Increase microwave concentration factor and optimize components for RF performance while maintaining resiliency towards high power microwaves. - Perform experimental validation of design improvements.					
Maskless Direct-Write Nanolithography for Defense Applications (U) The Maskless Direct-Write Nanolithography for Defense Applications 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	15.000	23.035	32.560	0.000	32.560

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
highly customized, application-specific ICs. In addition, this program will provide a cost effective manufacturing technology for low volume nanoelectromechanical systems (NEMS) and nanophotonics initiatives within the DoD. Transition will be achieved by maskless lithography tools, installed in the Trusted Foundry and in commercial foundries, which will enable incorporation of state-of-the-art semiconductor devices in new military systems, and allow for the cost-effective upgrade of legacy military systems. *FY 2009 Accomplishments:* - Demonstrated rotary stage at 10 meters per second. - Demonstrated static imaging on prototype Reflective E-Beam Lithograph (REBL) system. - Demonstrated dynamic imaging on prototype REBL system. *FY 2010 Plans:* - Demonstrate System Level Lithography Performance on a Linear Stage Demonstrator System. - Design, build, and test a rotary stage. - Integrate electron beam column and rotary stage demonstrator platform. - Design, build, and characterize an enhanced electron beam column for system alpha prototype experiments. *FY 2011 Base Plans:* - Design, build, and test an electronic mask device and exercise the data path for design information. - Design and build the next generation Rotary Stage Product Platform Prototype. - Develop and demonstrate a sensitive photoresist with acceptable performance for the 32 nanometer technology requirements.					
Deep Ultraviolet Avalanche Photodetectors (DUVAP) (U) This program demonstrated avalanche photodiodes (APDs) operating in the Geiger mode, i.e. capable of counting single photons with high gain. The APDs operate in the ultraviolet, in the band	1.139	0.000	0.000	0.000	0.000

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
centered at 280 nanometers (nm), and are designed to be insensitive to the solar flux. The two classes of materials pursued were Silicon Carbide (SiC) and Aluminum Gallium Nitride (AlGaN). The U.S. military has a need for compact, reliable, and cost-effective Geiger-mode photodetectors. Avalanche photodetectors offer high gain, low dark count, high reliability and robustness, and small form factor needed in future military applications. Technology will transition via industry. *FY 2009 Accomplishments:* - Demonstrated integrated solar-blind ultraviolet filter with appropriate cut-off. - Optimized materials for low defect density and reproducible device yield.					
Electronic & Photonic Integrated Circuits on Silicon (EPIC) (U) The Electronic & Photonic Integrated Circuits on Silicon (EPIC) program developed two critical alternative photonic technologies based on silicon substrates. The first thrust addressed active photonic components based on silicon, which do not rely on generating light within the material. While passive photonic components, such as waveguides, can be fabricated from silicon, silicon's indirect bandgap does not lend itself to fabricating active photonic components based on the generation of photons (lasers, amplifiers etc.). The EPIC program is transitioning via industry to optical communication and electronic warfare programs of interest to all Services. *FY 2009 Accomplishments:* - Demonstrated a functional Application Specific-EPIC using complementary metal-oxide semiconductor (CMOS) compatible processing.	2.125	0.000	0.000	0.000	0.000
Ultradense Nanophotonic Intrachip Communication (UNIC) (U) The Ultradense Nanophotonic Intrachip Communication (UNIC) program worked to demonstrate nanophotonic technology for access to on-chip ultra-dense systems and Input/Output (I/O) to/from a chip containing such ultra-dense systems. This technology will transition to industry.	11.000	0.000	0.000	0.000	0.000

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2009 Accomplishments: - Demonstrated extremely low power CMOS-compatible silicon photonic devices that demonstrate a path to on-chip optical communication links that are superior to conventional electronic messaging in single-die multiprocessor computing architectures. - Integrated arrays comprised of 4-wavelength silicon photonic transmitters and 10 gigabytes/second (Gbps) receiver.					
Analog Spectral Processors (ASP) (U) The Analog Spectral Processors (ASP) program leveraged 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 analog/digital converters and other front-end components. This enabled 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. *FY 2009 Accomplishments:* - Integrated filter banks with active components. - Conducted analysis of proposed front-end architecture. - Delivered breadboard-level filter banks to a third-party testing facility.	9.446	0.000	0.000	0.000	0.000
Microsensors for Imaging (MISI) (U) The Microsensors for Imaging (MISI) program established technology for extremely small, lightweight cameras sensitive in the short wave infrared spectrum for a wide range of applications. MISI initially focused on two important areas, micro-air vehicles and a head-mounted system. The camera components comprise a micro-system including optics, focal plane array and electronics	4.917	0.000	0.000	0.000	0.000

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
with display, energy source and illuminator included as the head-mounted system. The limitation of weight and power places demands on the sensor technology for exceptional image quality in a micro-package. This technology will have many DoD applications. This program will transition through industry performers into DoD systems, allowing integration into small robotic platforms and micro-air vehicles. *FY 2009 Accomplishments:* - Demonstrated megapixel arrays in micropackage that amplify low level optical signals with minimum excess noise while maintaining uniformity across the array. - Demonstrated operation at room temperature over military temperature range.					
Visual Processors Embedded for Real-Time Exploitation (VERTEX)* *Formerly titled Space, Time Adaptive Processing (STAP) BOY. (U) The Visual Processors Embedded for Real-Time Exploitation (VERTEX) program researched 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 (Registered Trademark). The VERTEX technology will transition to the Army. *FY 2009 Accomplishments:* - Developed and tested military application prototypes utilizing VERTEX technology.	2.824	0.000	0.000	0.000	0.000
High Operating Temperature - Mid-Wave Infrared (HOT MWIR) (U) The High Operating Temperature - Mid-Wave Infrared (HOT MWIR) program worked 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	8.374	0.000	0.000	0.000	0.000

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
detection and for imaging from fast moving platforms. The program technology will transition via industry for applications such as multi-band mid-wave or micro-detectors. *FY 2009 Accomplishments:* - Demonstrated thermal array with novel pixel structure showing low thermal mass and reduction in low frequency noise. - Demonstrated mid-wave photon detector array with dark current reduced to be comparable to the current from background radiation.					
Disruptive Manufacturing Technologies (DMT) (U) The Disruptive Manufacturing Technologies (DMT) program worked to achieve significant and pervasive cost savings, and/or decreases in cycle time, for existing or planned procurements. There has been a long-standing desire to replace traveling wave tube amplifiers (TWTAs), which are pervasive in nearly all electronic warfare (EW), information warfare (IW), radar, and communication systems with lower cost solid-state components. It will be replaced with solid-state hybrid microwave integrate circuit (HyMIC) modules developed by merging Polystrata and GaN technologies. The result will be a 10x reduction in TWTA cost for the Integrated Defensive Electronic Countermeasures (IDECM) program, a joint Navy-Air Force program. The program will transition into the joint Navy-Air Force IDECM program. *FY 2009 Accomplishments:* - Demonstrated a form-fit-function 160 W GaN amplifier ready for insertion into the IDECM decoy module.	2.392	0.000	0.000	0.000	0.000
Adverse Weather Landing System (U) The Adverse Weather Landing System program worked to provide the military pilot with an enhanced visual situational awareness capability to assist in making landing approaches in adverse	2.275	0.000	0.000	0.000	0.000

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	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
weather and low visibility conditions. The ability to eliminate poor visibility due to rain, fog, sand storms, and snow storms using electro-optical and signal processing techniques could save lives and loss of aviation equipment. This program will transition via industry. *FY 2009 Accomplishments:* - Conducted feasibility study incorporating the results from the static runway measurements, outside data collection sources, and dynamic flight tests. - Developed requirements to support the development of a high resolution sensor pertinent to limited visibility flight operations.					
Data in Optical Domain Network (DoD-Network) (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 Data in Optical Domain Network (DoD-Network) program explored 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 had two major areas of interest: the first focused 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 focused 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 will transition via industry to high-speed, high-capacity optical networking programs of interest to the Air Force. *FY 2009 Accomplishments:* - Developed an all-optical data router (ODR) with high data rate ports.	3.744	0.000	0.000	0.000	0.000

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	**FY 2010**	**FY 2011 Base**	**FY 2011 OCO**	**FY 2011 Total**
Precision Navigation	0.000	0.000	7.342	0.000	7.342
(U) The Precision Navigation program goal is to provide compact, rugged, low-power and extremely accurate means for determining position. The resulting systems will provide accurate tools for GPS-denied vehicle operation, on-foot cave and building exploration, precision munitions delivery and many other applications where previous options were too heavy, inaccurate, large or power-hungry. In order to achieve this, sensors will be developed to use internal and external reference information to maximum advantage. One component of the internal type is the development of a new class of microsystems capable of measuring the absolute angle of rotation with the ultra high precision, effectively operating as a mechanical integrator of rotation (MIR). The MIR will not rely on any absolute reference, but will define the reference itself in the absolute inertial space. The device will measure angle of rotation at an unprecedented precision of arc-seconds and a bandwidth in tens of kHz (all characteristics are at least 3 orders of magnitude better than the state-of-the-art). Another component of the program is the development of navigation grade integrated micro gyroscopes with the goal of achieving 0.01 deg/hr bias drift in very compact form factors (less than 1 cm3) and a total power consumption less than 5 mW per sense axis. Another key goal of this program is to harness external references where possible, which can be fused with internally referenced navigation signals to greatly improve performance. One approach to be pursued is the development of miniaturized atomic gradiometer arrays (AGA). Reducing previously bulky and high power AGA's to micro-scales will entail the use of nuclear magnetic resonance phenomena in extremely compact packages for timekeeping, rotation and magnetic field measurements. The AGA's will be deployed in arrays on the order of 10,000 individual sensors, each with the unprecedented target sensitivity of 0.1 femtoTesla (fT). This level of performance will yield not only highly capable navigation instruments making use of local gravitational variations, but also portable devices that are able to detect unexploded bombs/IEDs, camouflaged/faked military assets from platforms such as UAV's. When combined in systems, these new technologies will yield unprecedented navigational capabilities and help deny any advantage for adversaries who might interfere with GPS availability. Technology is expected to transition through industry.					

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2011 Base Plans: - Define miniaturization trade-offs with gyroscope performance to package and ruggedize. - Investigate in-ear plug design that protects ears from damaging sound levels while preserving hearing and sound localization. - Define functional requirements for key micro and nanotechnologies for the sequencer. - Demonstrate surface-enhanced Raman scattering using nanoplasmonic structures. - Demonstrate integration path for light sources and spherical atomic shells in arrays on a single wafer.					
Accomplishments/Planned Programs Subtotals	115.447	109.131	132.602	0.000	132.602

	FY 2009	FY 2010
Congressional Add: Center for Autonomous Solar Power *FY 2009 Accomplishments:* - Initiated solar power development.	4.000	0.000
Congressional Add: Hybrid Power Generation System *FY 2009 Accomplishments:* - Explored hybrid power technologies including new high-density power generators based on breakthrough configurations of permanent magnet materials, coil designs, and advanced power electronics.	1.200	0.000
Congressional Add: Ultra Low Power Electronics for Special Purpose Computers/Ubiquitous Computing	1.600	0.000

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B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010
FY 2009 Accomplishments: - Continued low power nano scale electronics development.		
Congressional Adds Subtotals	6.800	0.000

C. Other Program Funding Summary ($ in Millions)

N/A

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.