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

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	212.889	202.942	201.146	198.712	194.939	203.418	203.416
Centers of Excellence MT-07	5.625	5.500	0.000	0.000	0.000	0.000	0.000
MEMS and Integrated Microsystems Technology MT-12	80.077	39.470	57.057	63.886	71.806	80.721	80.720
Mixed Technology Integration MT-15	127.187	157.972	144.089	134.826	123.133	122.697	122.696

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

(U) The Advanced Electronics Technology program element is budgeted in the Advanced Technology Development Budget Activity because it seeks to design and demonstrate state-of-the-art manufacturing and 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

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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 and the MilTech Extension program.

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

	FY 2007	FY 2008	FY 2009
Previous President’s Budget	243.728	220.548	232.383
Current Budget	212.889	202.942	201.146
Total Adjustments	-30.839	-17.606	-31.237
Congressional program reductions	-10.000	-21.346	
Congressional increases	0.000	3.740	
Reprogrammings	-14.600		
SBIR/STTR transfer	-6.239		

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(U) Change Summary Explanation:

FY 2007	Decrease reflects the Section 8043 Recission, the OMNIBUS reprogramming, an internal reprogramming, and the SBIR/STTR transfer.
FY 2008	Decrease reflects a PE execution adjustment and reductions for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions; offset by congressional adds for Computing and NanoscaleElectronic Processing, MilTech Extension program, and Ultra Low Power Electronics for Special Purpose Computers.
FY 2009	Decrease reflects the completion of several programs in the Mixed Technology Integration Project (MT-15), including Ultra-Wideband Technology, High Operating Temperature – Mid-Wave Infrared (HOT MWIR), Space, Time Adaptive Processing (STAP) BOY, and Electronics and Phonic Integrated Circuits on Silicon; offset by an increase in MEMs and Integrated Microsystems Project (MT-12) for new chip scale and nanofabrication efforts.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Centers of Excellence MT-07	5.625	5.500	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 and the Defense Techlink Rural Technology Transfer Project. 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. The Defense Techlink Rural Technology Project helps businesses transition innovative technologies to the DoD.

(U) Program Accomplishments/Planned Programs:

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

(U) Program Plans:

FY 2007 Accomplishments:
- Assessed the Institute for Advanced Flexible Manufacturing's performance and worked toward transitioning from DoD to state/private support.

FY 2008 Plans:
- Continue to assess the Institute for Advanced Flexible Manufacturing's performance and transition from DoD to state/private support.

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	FY 2007	FY 2008	FY 2009
Defense Techlink Rural Technology Transfer Project	1.625	1.500	0.000

(U) Program Plans:

FY 2007 Accomplishments:

– Provided funding for the Defense Techlink Rural Technology Transfer Project.

FY 2008 Plans:

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

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

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
MEMS and Integrated Micro-systems Technology MT-12	80.077	39.470	57.057	63.886	71.806	80.721	80.720

(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 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) <u>Program Accomplishments/Planned Programs:</u>

	FY 2007	FY 2008	FY 2009
Micro Power Generation	6.094	3.000	0.000

(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:

FY 2007 Accomplishments:
- Demonstrated capabilities in fuel processing, energy conversion to electricity, and thermal and exhaust management.
- Demonstrated MEMS micro heat engines utilizing micropower sources.

FY 2008 Plans:
- 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.

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	FY 2007	FY 2008	FY 2009
Harsh Environment Robust Micromechanical Technology (HERMIT)	10.585	2.767	3.990

(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 microelectromechanical systems (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:

FY 2007 Accomplishments:

- Established 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.
- Demonstrated engineered materials and/or surface treatments that render a micromechanical device impervious to its surroundings or operating environment.

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FY 2008 Plans:
- Demonstrate essential elements (e.g., thermistors, heaters, getters, etc.) needed for low power control of the operating environment surrounding a micromechanical device.

FY 2009 Plans:
- 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 2007	FY 2008	FY 2009
Chip-Scale Micro Gas Analyzers	20.504	5.267	0.000

(U) The Chip-Scale Micro Gas Analyzers program will utilize 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/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:

FY 2007 Accomplishments:
- Established design trade-offs in (column) length vs. species separation efficiency for micro-scale gas chromatographs, mass spectrometers, resonator-based separation mechanisms, etc.

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- Demonstrated MEMS-enabled, micro-scale preconcentrators and explored the degree to which they enhanced separation efficiency and species detectability.

FY 2008 Plans:
- Demonstrate MEMS-enabled, micro-scale separation columns, ionizers, electromagnetic field generators, vacuum pumps, gas sensor arrays, calibration sources, all needed for separation-based analyzers.
- 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 2007	FY 2008	FY 2009
MEMS Exchange	7.250	2.908	1.000

(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 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:

FY 2007 Accomplishments:
- Demonstrated online software capable of error checking and optimized process flow input by users, which reduced the turn-around time per run and increased success rates.
- Inserted a MEMS process module into the MEMS Exchange repertoire and made it available for use.

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FY 2008 Plans:
- 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.

FY 2009 Plans:
- Insert MEMS technology into three DoD applications using MEMS Exchange as the fabrication vehicle.

	FY 2007	FY 2008	FY 2009
Low Power Micro Cryogenic Coolers	5.230	3.450	0.810

(U) The Low Power Micro Cryogenic Coolers 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:

FY 2007 Accomplishments:
- Demonstrated thermal isolation of >10,000 kilowatt (K/W) in a silicon micromachining process.
- Demonstrated on-chip cooling to 77 kilo (K) using a photonic fiber heat exchanger.
- Demonstrated new localized on-chip cooler approaches using integrated thermoelectric coolers and photonic heat exchangers.

FY 2008 Plans:
- Demonstrate micro-scale coolers capable of providing the needed cryogenic temperature while still fitting into a miniature size, with sufficient efficiency for low power operation.
- Demonstrate heat exchangers, Joule-Thompson plugs, valves, pumps, all needed for cryo-cooler implementation.

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FY 2009 Plans:
- Integrate micro cooler components together with sufficiently isolated devices to-be-cooled to yield a single chip system consuming very little power.

	FY 2007	FY 2008	FY 2009
Microsystem Integrated Navigation Technology (MINT)*	9.000	5.230	7.096

*Formerly titled Chip-Scale Atomic Sensors.

(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.

(U) Program Plans:

FY 2007 Accomplishments:
- Developed a tunable microwave local oscillator to excite and select different hyperfine transitions.

FY 2008 Plans:
- Develop technology to dramatically reduce bias drifts in Complementary Metal-Oxide Semiconductor (CMOS)-integrated MEMS accelerometers and gyros.
- Develop CMOS-MEMS sensors for precision navigation aids such as velocity ranging and zero-velocity updating.

FY 2009 Plans:
- Reduce power and volume requirements.
- Develop technologies to harvest power through energy scavenging.

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	FY 2007	FY 2008	FY 2009
Thermal Ground Plane (TGP)*	15.894	7.848	8.161

*Formerly titled Site-Specific Thermal Management (SSTM).

(U) The Thermal Ground Plane (TGP) 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 TGP 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:

FY 2007 Accomplishments:

– Initiated review of thermal management approaches.

FY 2008 Plans:

– Identify and apply new integrated technologies for the thermal management of microsystems.

FY 2009 Plans:

– Develop and integrate cooling approaches using new materials.

	FY 2007	FY 2008	FY 2009
Micro-Beam Clocks	2.602	2.000	4.000

(U) The Micro-Beam Clock 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

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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:

FY 2007 Accomplishments:
- Generated sufficient atom flux using adsorption-desorption control at microscale.
- Detected atoms in flight using micro-cantilever array – Brownian noise limited.

FY 2008 Plans:
- Determine permanent magnet laser cutting at microscale.
- Determine High B-field gradients at microscale.

FY 2009 Plans:
- Determine pressure measurement in presence of high magnetic field with MEMS pressure sensors.

	FY 2007	FY 2008	FY 2009
Nano-Electro-Mechanical Computers (NEMS)	1.818	7.000	9.000

(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 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. 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 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.

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(U) Program Plans:

FY 2007 Accomplishments:
- Developed nanomechanical switch-based logic in semiconductors, metals and insulators.

FY 2008 Plans:
- Develop mechanical gain elements for analog amplification using effects such as buckling and electromechnical phase changes.

FY 2009 Plans:
- Develop NEMS switches in direct bandgap materials to enable optical functionality with switches.

	FY 2007	FY 2008	FY 2009
Chip-Scale Auto Pilot	0.000	0.000	3.000

(U) The Chip-Scale Auto Pilot program will develop a new chip-scale subsystem for unmanned aerial vehicles (UAVs), which will provide on-board autonomous capabilities for collision avoidance and maneuvering support. The system will use data from miniature inertial sensors, imagers, and other sensors, and a data-fusion algorithm to produce control signals for the facilities on an existing UAV, such as the Wireless Application Service Provider (WASP). The goal is to allow operators of UAVs in dense urban environments to focus on high-level objectives, and to leave responsibility for survival and maneuvering to the UAV.

(U) Program Plans:

FY 2009 Plans:
- Develop mm-scale navigation system merging signals from Inertial Measurement Unit (IMU), Vision, GPS, and Timing.
- Fuse data from complimentary systems for on-board, autonomous collision avoidance and basic navigation functions.

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	FY 2007	FY 2008	FY 2009
Micropumps	0.000	0.000	3.000

(U) The Micropumps program will address the current need for chip-scale micropumps with significantly improved performance (~10^{-6} Torr and less than 1 cm^3 in volume). Microscale pumps have been developed by numerous research groups, but many microsystems still employ off-chip pumping because available microscale pumps do not meet application requirements. Pumping is crucial for distributing fluids through a microsystem and for providing a vacuum for various technologies, including micro mass spectrometers, nanoscale detectors, RF resonators, and a variety of other Nano MEMS devices. In many cases, the limiting factor in development of an integrated, low-power, micro total analysis system or electronic device is the pump. The goal of the Micropumps program is to provide improvements in microscale pumping capabilities to facilitate and greatly enhance operation of a variety of microsystems for DoD applications.

(U) Program Plans:

FY 2009 Plans:

- Demonstrate new microscale pump designs with high compression ratios.
- Demonstrate microscale pumps with high pump speeds and high vacuum levels.

	FY 2007	FY 2008	FY 2009
NanoCAD	0.000	0.000	3.000

(U) One of the key problems with nano electro-mechanical system (NEMS) and microelectromechanical systems (MEMS) component development is the time lag between device conception to manufacturing or even prototyping. This long development time is often due to the many number of iterations needed to make devices, which involve multiphysics domains. Furthermore, the cost of manufacturing tends to be determined in the future rather than in the beginning, as it is the case with other developed technologies like CMOS. The goal of the NanoCAD program is to reduce the time to market for MEMS and NEMS components.

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(U) Program Plans:
FY 2009 Plans:
- Develop natural graphic modeling techniques to take mechanical and electrical concepts and turn them into process flows.
- Develop reduced variable models that connect the nanoscale physics (e.g. contact physics, thermal and electrical conduction) to micro-scale to macro-scale physics on a PC workstation.
- Develop a simulation database from different working groups.

	FY 2007	FY 2008	FY 2009
Magnetic MEMS	0.000	0.000	3.000

(U) Recent breakthroughs in 3-dimensional (3-D) fabrication, including work on DARPA's 3-D Micro Electromagnetic Radio Frequency Survey (MERFS) program, as well as development of photo-patternable glasses, patternable ceramics, and other technologies have now opened up the potential of 3-D fabrication. This effort will explore the potential of using these new fabrication technologies to capture magnetic phenomenology and effect miniaturization and improved performance of a range of critical military systems.

(U) Program Plans:
FY 2009 Plans:
- Utilize 3-D fabrication technologies to demonstrate range of new high-performance 3-D magnetic components and systems.

	FY 2007	FY 2008	FY 2009
Chip-Scale Direct Sampling Receivers (CSDSR)	0.000	0.000	2.000

(U) The Chip-Scale Direct Sampling Receiver (CSDSR) program aims to realize true software-defined radio front-ends that feed RF input signals directly to analog-to-digital converters (ADC's), allowing the rest of the radio to be realized digitally and completely reconfigurable via software. The key to making this possible is the use of technologies capable of isolating channels (not bands, but channels with <0.05% bandwidth) directly after the antenna, removing all out-of-*channel* interferers before they arrive at the low noise amplifier (LNA)/ADC input,

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hence substantially relaxing the dynamic range required by the LNA/ADC to achieve a given receiver jam-resistance. In essence, the removal of all interferers by the channelizer allows the ADC to operate without the need to reject strong interferers, thereby without the need for a high dynamic range. This allows the use of fewer bits, making it possible for the ADC to handle GHz input frequencies without excessive power consumption. The CSDSR program would ultimately make possible universal receivers capable of operating under conceivably any communication standard by merely reconfiguring itself.

(U) Program Plans:
FY 2009 Plans:
- Demonstrate software-defined radio functions.
- Demonstrate an array of nanomechanical resonators for software-defined communications and jam-resistant applications.

	FY 2007	FY 2008	FY 2009
Micromechanical Amplifiers	0.000	0.000	3.000

(U) The Micromechanical Amplifiers program will realize micromechanical circuits that amplify signals (e.g., for communications, sensing, etc.) with substantially better efficiency, lower noise, and higher dynamic range, than currently achievable via state-of-the-art electronic implementations.

(U) Program Plans:
FY 2009 Plans:
- Demonstrate and optimize new approach for resonant switch-based mechanical amplifier.

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	FY 2007	FY 2008	FY 2009
Chip-Scale High Energy Atomic Beams	0.000	0.000	3.000

(U) The Chip-Scale High Energy Atomic Beams program will develop chip-scale high-energy atomic beam technology by developing high-efficiency radio frequency (RF) accelerators, either linear or circular, that can achieve energies of protons and other ions up to a few mega electron volts (MeV). Chip-scale integration offers precise, micro actuators and high electric field generation at modest power levels that will enable several order of magnitude decreases in the volume needed to accelerate the ions. Furthermore, thermal isolation techniques will enable high efficiency beam to power converters, perhaps making chipscale self-sustained fusion possible.

(U) Program Plans:

FY 2009 Plans:

- Develop 0.5 MeV proton beams and collide onto microscale B-11 target with a fusion Q (energy ratio) > 20, possibly leading to self-sustained fusion.
- Develop neutron-less fusion allowing safe deployment for handheld power sources.
- Develop microscale isotope production by proton beam interaction with specific targets.
- Explore purification of isotope systems.
- Develop hand-held pico-second laser systems to introduce wakefield accelerators for x-ray and fusion sources.

	FY 2007	FY 2008	FY 2009
Microtechnologies for Air-Cooled Exchangers (MACE) Heat Sink Enhancement	0.000	0.000	3.000

(U) The Microtechnologies for Air-Cooled Exchangers (MACE) Heat Sink Enhancement program will explore emerging concepts for enhancement of the performance of heat rejection systems throughout the DoD. Specific program goals include the reduction of the thermal resistance by a factor of 4x and reducing the power consumption of the cooling system by 3x. Successful projects will apply MACE technologies to a customer-specified application.

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(U) Program Plans:

FY 2009 Plans:

– Demonstrate models, measurements, and Single-Fin device.
– Establish functional full-scale heat sink 4”x4”x1” with 4x reduction in thermal resistance and 3x improvement in coefficient of performance.

	FY 2007	FY 2008	FY 2009
Small Scale Systems Packaging	1.100	0.000	0.000

(U) The Small Scale Systems Packaging program developed small-scale electronics packaging technology for more efficient microelectronics manufacturing.

(U) Program Plans:

FY 2007 Accomplishments:

– Developed advanced roll-to-roll manufacturing processes for microelectronics.

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

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Mixed Technology Integration MT-15	127.187	157.972	144.089	134.826	123.133	122.697	122.696

(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), 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

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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) <u>Program Accomplishments/Planned Programs:</u>

	FY 2007	FY 2008	FY 2009
Adaptive Photonic Phased Locked Elements (APPLE)	11.300	10.521	9.792

(U) The goal of the Adaptive Photonic Phased Locked Elements (APPLE) 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:

FY 2007 Accomplishments:
- Demonstrated a small (25 millimeter diameter) single aperture that can handle a low level of input laser power (50 Watts) and was able to support an initial demonstration of a controlled combination of outputs from multiple apertures.

FY 2008 Plans:
- Demonstrate the controlled combining of the outputs of multiple (7) small individual apertures at low input powers.
- Demonstrate a small single aperture that can handle a high level of input laser power (200 Watts).

FY 2009 Plans:
- Demonstrate high power combined output of multiple (7) small individual apertures.
- Demonstrate atmospheric compensation in the real atmosphere at low powers.

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	FY 2007	FY 2008	FY 2009
Data in Optical Domain Network (DoD-Network)	9.299	7.200	7.851

(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:

FY 2007 Accomplishments:
- Demonstrated that small buffers (achievable in the optical domain) have minimal impact on the network performance when the network traffic consists of a large number of simultaneous unsynchronized Transmission Control Protocol flows.
- Demonstrated all optical and hybrid clock recovery.

FY 2008 Plans:
- Demonstrate all-optical, Indium Phosphide (InP)-based, integrated photonic, packet forwarding chip which supports forwarding and re-labeling of optical packet headers.
- Demonstrate the first fully monolithic separate absorption and modulation wavelength converter operating "error-free".

FY 2009 Plans:
- Develop an all-optical data router with high data rate ports.

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	FY 2007	FY 2008	FY 2009
Microantenna Array Technology & Applications (MIATA)	2.275	1.821	2.000

(U) The goal of the Microantenna Array Technology & Applications (MIATA) program is to develop low-cost arrays that can sense both Millimeter Wave (MMW) and 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, ultra-wide band 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 resulting MMW cameras will be lighter, cheaper, and have a higher performance than conventional cameras. The improved MIATA diodes will have low-gain low-noise amplifiers (LNAs) integrated on the focal plane. Applications include imagers for concealed weapon detection and helicopter landings in brownout. The MIATA program is planned for transition to the Army Research Laboratory at the conclusion of Phase III, which is anticipated to be completed in FY 2009.

(U) Program Plans:

FY 2007 Accomplishments:
- Achieved 95 gigahertz (GHZ): Noise Equivalent Temperature Detection (NETD) $\leq$ 20 Kelvin (K) in a 2x2 array.
- Achieved 8-12 um: NETD $\leq$ 0.1 K in an 8x8 array.

FY 2008 Plans:
- Achieve 95 GHZ: NETD $\leq$ 2 K in an 8x8 array.

FY 2009 Plans:
- Achieve 8-12 um: NETD $\leq$ 0.02 K in a 64x64 array.

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	FY 2007	FY 2008	FY 2009
Ultra-Wide Band Technology	5.500	10.500	0.000

(U) Radar array antennas that use the Ultra-Wide Band Technology 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 Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C^4ISR) platforms and wide band phased-array antenna systems at the conclusion of Phase III, which is anticipated to be completed by FY 2008.

(U) Program Plans:

FY 2007 Accomplishments:
- Developed and demonstrated optical modulators, which exhibit low switching voltages and incorporate a long effective electrode length.
- Demonstrated > +27 decibel milliwatt radio frequency power handling in a single photodiode at 6 gigahertz.

FY 2008 Plans:
- Demonstrate > 40 decibels transmit/receive isolation in a photonic circulator over a larger bandwidth in the X-band.
- Demonstrate photodiodes with 3rd order output intercept points higher than state-of-art.
- Demonstrate a photonic circulator with world record gain and low noise figure in the receive mode and with improved transmit/receive isolation over a large bandwidth in the X-band.

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	FY 2007	FY 2008	FY 2009
Laser-Photoacoustic Spectroscopy (L-PAS)	5.238	0.000	0.000

(U) The Laser-Photoacoustic Spectroscopy (L-PAS) program developed and demonstrated 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 discriminated a wide variety of possible chemical agents, explosives, and narcotics in the presence of diverse background environments. L-PAS transitioned prototype chemical agent sensors to the Joint Science and Technology Office (JSTO), Defense Threat Reduction Agency for evaluation. To that end, JSTO and DARPA worked closely to ensure that the final program addressed the joint Chemical/Biological community needs.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated working prototypes that have a sensitivity to <1 part per billion (ppb) at a false alarm rate of better than 10^{-6}.
- Demonstrated a major improvement in performance (measured in terms of sensitivity) over the Joint Chemical Agent Detector system, which is the next generation chemical sensor currently under development.
- Developed tuned lasers with a range of $\pm$ 40 nanometers (nm).
- Fabricated infrared micro-photonics.
- Assembled complete quantum laser diode modules with mid- and long- wave IR ranges.
- Developed tunable Quantum Cascade Lasers with resonant acoustic chamber detection cell.

	FY 2007	FY 2008	FY 2009
High Operating Temperature - Mid-Wave Infrared (HOT MWIR)	8.870	19.405	0.000

(U) The objective of the High Operating Temperature - Mid-Wave Infrared (HOT MWIR) 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

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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 will be 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.

(U) Program Plans:

FY 2007 Accomplishments:
- Designed new approaches necessary to reduce detector dark current and noise.
- Amplified the low-level signal in multi-band mid wave detectors, showing potential for high sensitivity and fast response in room temperature arrays.
- Developed micro-detectors, which collect signals from a large area while reducing the volume available for detector noise generation.
- Demonstrated carrier extraction techniques in the laboratory to show potential to reduce excess current while maintaining high-speed signal levels.

FY 2008 Plans:
- Demonstrate 256x256 arrays operating at 250 kelvin with X8 – X10 lower dark current.
- Establish pixel design and test arrays for mega-pixel room temperature arrays.
- Demonstrate high density arrays with dual band (Mid/Long Wavelength Infrared) response.

	FY 2007	FY 2008	FY 2009
Visible/Short Wave IR - Photon Counting	3.880	5.297	5.004

(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

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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:

FY 2007 Accomplishments:
- Developed unique electronic read-outs with internal gain that boost low level signals above output amplifier noise.
- Developed potential approaches to include distributed amplification in the read-out signal chain, avalanche multiplier gain internal to the pixel.
- Reduced short wave infrared detector dark current, resulting in lower power man-portable imaging sensors.

FY 2008 Plans:
- Demonstrate read-out integrated circuit for short wave infrared with less than 10 noise electrons.

FY 2009 Plans:
- Integrate low noise focal plane array into a mega-pixel array format and demonstrate room temperature imaging.
- Demonstrate single photon counting devices for ultra low noise imaging.

	FY 2007	FY 2008	FY 2009
Electronic & Photonic Integrated Circuits on Silicon (EPIC)	12.548	5.223	0.000

(U) The Electronic & Photonic Integrated Circuits on Silicon (EPIC) 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 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

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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:

FY 2007 Accomplishments:
- Developed process for integration of germanium-based photodetectors with an integrated amplifier in foundry-compatible complementary metal-oxide-semiconductor process.
- Demonstrated optically-implemented microwave-frequency nulling filter to drop unwanted channels.

FY 2008 Plans:
- Demonstrate 40 gigabytes per second capacity transceiver chip with four wavelengths.
- Demonstrate a wideband radio frequency channelizer with multiple channels and nulling of at least a single channel.
- Increase integration complexity of electronics and photonics to include hundreds of photonics components.

	FY 2007	FY 2008	FY 2009
Space, Time Adaptive Processing (STAP) BOY	4.899	4.240	1.000

(U) The Space, Time Adaptive Processing (STAP) BOY 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 GPUs resulting from competition in the multi-billion dollar international electronic entertainment industry. Particularly relevant advantages of recent GPUs 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 2009.

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(U) Program Plans:

FY 2007 Accomplishments:
- Developed and characterized a prototype architecture using a single GPU and a Field Programmable Gate Array input-output structure.

FY 2008 Plans:
- Demonstrate that the prototype system is capable of sustaining 100 giga floating point operations per second (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.

FY 2009 Plans:
- 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 2007	FY 2008	FY 2009
Vertically Integrated Sensor Arrays (VISA)	3.000	6.713	0.000

(U) The Vertically Interconnected Sensor Arrays (VISA) program will develop and demonstrate vertically interconnected, focal plane array read-out technology capable of more than 20-bits of dynamic range, over an order-of-magnitude higher than current state-of-the-art, enabling significant advances in the functionality of infrared systems. Vertical interconnections between the detectors and the read-outs that avoid first going through row-column multiplexers will allow for high frame rates concurrent with high-resolution images.

(U) The program will expand architectures for three-dimensional focal plane arrays, where multiple levels of signal processing are integrated into each pixel in the array, to include multiple processing layers, higher density vias (small openings in an insulating oxide layer that enable electrical connections, e.g., between layers) 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. Defense applications include mid-/long-wavelength target acquisition systems for air and ground, smart missile seekers, anti-jamming, and imaging through high intensity sources. This effort will transition through the current VISA industrial performers into a wide range of military imaging systems including the capability to image targets in low contrast, high clutter, or low light scenes such as a low signature cruise missile against sun-glint from the ocean.

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated high dynamic range imaging sensors with an analog to digital converter at each pixel in the array.
- Designed and developed three-dimensional focal plane architectures with multiple levels of signal processing at each detector in the array.

FY 2008 Plans:

- Develop thru-via and interconnection technology with greater than 99% operability on 256x256 arrays.
- Perform imaging showing temperature gradients in object at a high temperature, demonstrating capability of high dynamic range.
- Demonstrate wafer bonded interconnect showing feasibility of high-density pixel arrays, beyond current indium bump interconnect technology.
- Demonstrate feasibility of high-density vias to increase circuit area available for processing.
- Develop advanced vertically integrated sensor architecture with capability to integrate high dynamic range into high density pixel.

	FY 2007	FY 2008	FY 2009
Analog Spectral Processors (ASP)	4.500	13.483	13.877

(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 analog/digital 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:

FY 2007 Accomplishments:

- Completed design and modeling of novel front-end architecture, and derived specifications for filter and switch components.
- Developed and tested novel filter and switch components operating from 20 megahertz (MHz) – 6 gigahertz (GHz).

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- Conducted independent verification of component performance.
- Completed Preliminary Design Review utilizing filter results to demonstrate component feasibility.

FY 2008 Plans:
- Demonstrate intimate integration of filter and switch components.
- Demonstrate pre-selector, intermediate frequency, and analog filter sensor banks.
- Complete Conceptual Design Review.

FY 2009 Plans:
- Integrate filter banks with active components.
- Demonstrate complete front end meeting size, power, and performance objectives.

	FY 2007	FY 2008	FY 2009
Electromagnetic Pulse Tolerant Microwave Receiver Front End (EMPIRE)*	5.525	5.100	5.690

*Formerly titled All-Dielectric Non Electronic RF Front-End (ADNERF).

(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. By eliminating the metallic antenna, a secondary goal is to effect a significant reduction in detectable radar cross section.

(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 electro-magnetic pulse weapons.

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(U) Program Plans:

FY 2007 Accomplishments:

- Identified and developed innovative dielectric materials with high dielectric constant and low loss.

FY 2008 Plans:

- Design and implement doubly resonant (RF and optical) antenna structures in support of non-electronic signal transduction.

FY 2009 Plans:

- Demonstrate dramatic reduction in RF front-end susceptibility to electromagnetic pulses while maintaining militarily useful system.

	FY 2007	FY 2008	FY 2009
Microsensors for Imaging (MISI)*	3.757	3.920	4.917

*Formerly titled High Gain Optical Transceiver on a Chip.

(U) The Microsensors for Imaging (MISI) program establishes technology for extremely small, lightweight cameras sensitive in the short wave infrared for a wide range of applications. MISI is 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 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. In the micro-air vehicle application, the weight goal is ten (10) grams, (including the optics, detector and electronics) for a camera with a degree field of view and recognition range of one-hundred meters. In the head-mount application, the weight goal of three-hundred fifty (350) grams includes the sensor with display and power source. This program will transition through industry performers into DoD systems, allowing integration into small robotic platforms and micro-air vehicles.

(U) Program Plans:

FY 2007 Accomplishments:

- Completed array and integrated package design to achieve microsensor in extremely small package suitable for microvehicle applications.
- Completed design to demonstrate stable device operation over a wide temperature range.

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FY 2008 Plans:
- Demonstrate imaging arrays in micropackage for both man-portable and micro-vehicle applications, with package thermal stability for long-lifetime operation.
- Complete design of short wave arrays for helmet mounted applications compatible with illuminator and compact system design.

FY 2009 Plans:
- Demonstrate megapixel arrays in micropackage that amplify low level optical signals with minimum excess noise while maintaining uniformity across the array.
- Demonstrate operation at room temperature over military temperature range.

	FY 2007	FY 2008	FY 2009
Maskless Direct-Write Nanolithography for Defense Applications	19.000	22.600	20.100

(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 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.

(U) Program Plans:

FY 2007 Accomplishments:
- Completed and delivered End-to-End System Error Budget and throughput model.

FY 2008 Plans:
- Design, build and integrate a demagnification optics system and wafer adapter, and achieve a patterning resolution on the wafer of about 1 micron.
- Characterize prototype Reflection Electron Branch Lithography (REBL) system to validate simulation results.

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FY 2009 Plans:
- Demonstrate rotary stage at 10 meters per second.
- Demonstrate static imaging on prototype REBL system.
- Demonstrate dynamic imaging on prototype REBL system.

	FY 2007	FY 2008	FY 2009
Stand-off Solid Penetrating Imaging*	3.058	3.942	5.900

*Formerly titled Stand-off Detection and Identification.

(U) The Stand-off Solid Penetrating Imaging program will detect and identify explosive threats at a stand-off distance, a critical requirement for 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. This program will allow X-ray imaging at a distance of up to 50 meters.

(U) Program Plans:

FY 2007 Accomplishments:
- Demonstrated in the laboratory unique image reconstruction techniques suited to imaging through visually opaque objects at a 50 – 100 meter stand-off distance.

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FY 2008 Plans:
- Assess X-ray source requirements, such as power, size, weight, focal spot, and tube configuration including various beam formation techniques.
- Implement X-ray imaging reconstruction for remote vehicle applications.

FY 2009 Plans:
- Trade-off source requirements for more efficient sensor technology, notably two-dimensional arrays of cadmium telluride or silicon carbide with high spatial resolution.
- Demonstrate X-ray image at 50 – 100 meters, and address issues including efficient radiation coupling into the sensor, spectral selectivity, and signal enhancement techniques.

	FY 2007	FY 2008	FY 2009
Deep Ultraviolet Avalanche Photodetectors (DUVAP)	3.500	3.171	2.434

(U) Recent advances in Wide-Bandgap Semiconductor materials have opened new possibilities for exploiting the ultra-violet (UV) region of the electromagnetic spectrum. The current Deep Ultraviolet Avalanche Photodetectors (DUVAP) program has been successful in advancing the state of the art of UV light emitting diodes and laser diodes. This follow-on program seeks to develop high sensitivity, compact UV detectors. Specifically, avalanche photodiodes (APDs) 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 DUVAP 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:

FY 2007 Accomplishments:
- Demonstrated Geiger mode operation at 280 nanometers.
- Determined maximum defect density for stable avalanche gain.
- Demonstrated solar blind UV filter compatible with the APD structure.

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FY 2008 Plans:
- Develop Optimized Geiger mode device.
- Optimize E Materials for low defect density and reproducibly high device yield.
- Demonstrate Solar-blind UV filter with on/off cutoff of 103, integrated with a discrete device.

FY 2009 Plans:
- Demonstrate 1 cm^2 array of Geiger mode APDs with dark count rate <10 kHz and solar rejection ratio of 106.

	FY 2007	FY 2008	FY 2009
WIFI-EYEPOD	0.000	3.492	6.000

(U) The WIFI-EYEPOD program will transform the dismounted soldier into a semi-autonomous direct current (DC) - 10 GHz sensor/comms/signals intelligence 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.

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(U) Program Plans:

FY 2008 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 silicon-germanium (SiGe) and 90nm complementary metal-oxide-semiconductor.

FY 2009 Plans:

- Integrate a modem, quad-band antenna, and Ultra-Wide Band antenna and transmitter with commercial interface to create an embedded processing unit.

	FY 2007	FY 2008	FY 2009
Airplane on a Chip (AOC) - Chip Scale Avionics	0.000	0.000	2.000

(U) The Airplane-on-a-Chip (AOC) - Chip Scale Avionics program seeks to exploit continued advances in integrated Microsystems technology to remake the stovepipe/legacy avionics architecture which are 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.

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(U) Program Plans:
FY 2009 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 programs.
- Deliver an avionics system approaching one cubic centimeter in volume with power dissipation on the order of tens of milliwatts.

	FY 2007	FY 2008	FY 2009
Ultradense Nanophotonic Intrachip Communication (UNIC)*	9.486	5.500	10.950

*Formerly titled Nanophotonics for Ultradense On-chip Communications.

(U) The goal of the Ultradense Nanophotonic Intrachip Communication (UNIC) program is to demonstrate nanophotonic technology for (1) access to on-chip ultra-dense systems and (2) Input/Output (I/O) to/from a chip containing such ultra-dense 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 ultra-dense systems, techniques for efficient high capacity/bandwidth I/O of data to and from the chip. This technology will transition via industrial performers developing ever faster and more complex processing such as real-time pattern matching, target recognition, image processing and THz class command-and-control networks.

(U) Program Plans:
FY 2007 Accomplishments:
- Initiated high performance, low power active and passive photonics at ~ 1 mm size-scale for on-chip global interconnects for significantly improved processor performance.

FY 2008 Plans:
- Create novel designs to demonstrate extremely low power complementary metal-oxide-semiconductor (CMOS) compatible silicon photonic devices.

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FY 2009 Plans:
- Demonstrate 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.

	FY 2007	FY 2008	FY 2009
Hemispherical Array Detector for Imaging (HARDI)	4.744	3.486	4.682

(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.

(U) Program Plans:

FY 2007 Accomplishments:
- Demonstrated a manufacturing process for fabrication on hemispherical surface and developed high detectivity materials over broad wavelength range.

FY 2008 Plans:
- Develop high efficiency detector materials.
- Demonstrate curved single pixel detector.

FY 2009 Plans:
- Develop improved materials for Visable-Near IR-Shortwave IR (VIS-NIR-SWIR).
- Demonstrate a curved focal plane array.

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	FY 2007	FY 2008	FY 2009
Day/Night Adaptive Imager	0.000	3.000	5.000

(U) Low light level imaging has proven its value by 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 will incorporate noiseless detection and processing of individual photon events to leverage the benefits of solid state imaging and take 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. This technology will transition through industrial performers into eventual systems for sniper scope devices and electronic imaging sensors for micro-air vehicles.

(U) Programs Plans:

FY 2008 Plans:

- Develop ultra-wide dynamic range imaging sensors that count individual photon events and also operate in high light level.

FY 2009 Plans:

- Reduce dark counts for room temperature operation.
- Demonstrate integrated functions, such as day/night imaging with covert signal detection.

	FY 2007	FY 2008	FY 2009
Miniature, Room Temperature, Ultra-sensitive Magnetic Sensor (MRUMS)	0.000	3.500	6.500

(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-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. This technology will transition into DoD systems via industry.

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(U) Program Plans:

FY 2008 Plans:

- Demonstrate proof of concept of compact single room temperature sensor for magnetic field.

FY 2009 Plans:

- Demonstrate high sensitivity compact single room temperature sensor for magnetic field.

	FY 2007	FY 2008	FY 2009
Contiguous Multi-Mega-pixel Infrared Imaging Arrays	0.000	3.000	5.000

(U) The Contiguous Multi-Mega-pixel Infrared Imaging Arrays 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 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. This technology will transition via industry.

(U) Program Plans:

FY 2008 Plans:

- Develop approaches for contiguous butting of large infrared arrays without line loss at array intersection.

FY 2009 Plans:

- Demonstrate large arrays with integral data pre-screening to highlight potential targets and areas of interest.

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	FY 2007	FY 2008	FY 2009
High Resolution Short Wave Infrared/High Density Infrared Retina	0.000	4.000	7.000

(U) The High Resolution Short Wave Infrared/High Density Infrared Retina 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. This program is directed at reducing pixel size to the dimension of the wavelength, in the shortwave infrared (SWIR), mid-wave infrared (MWIR) and long-wave infrared (LWIR). The SWIR is the most demanding case since the wavelength is the shortest. This technology will transition into eventual DoD systems through program industrial performers.

(U) Program Plans:

FY 2008 Plans:
- Develop material growth and array processing for extremely high-resolution short wave infrared with pixel size on the order of the wavelength.

FY 2009 Plans:
- 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 two microns and show contact method to small pixel structure.

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	FY 2007	FY 2008	FY 2009
Control of Optical Properties of Infrared Semiconductors	0.000	3.250	5.000

(U) The Control of Optical Properties of Infrared Semiconductors 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 a room temperature imager has the potential to increase sensitivity five to ten times expanding the application base of room temperature infrared imagers. This program will develop materials where the apparent temperature can be modulated above and below the background level, with an average level of zero. Imagers without the specific code used will not have capability to detect the modulation. Imagers cued to the code will detect the modulated signal. This program will transition to defense systems via industry.

(U) Program Plans:

FY 2008 Plans:

- Demonstrate detection of modulated signal with zero average using existing 3-5um NL material.

FY 2009 Plans:

- Reduce Long-Wave Infrared (LWIR) dark current and material doping by a factor of 10.
- Investigate growth of LWIR material on silicon substrates for larger area, lower cost and longer range.

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	FY 2007	FY 2008	FY 2009
Cost Effective Low Volume Nanofabrication	0.000	0.000	3.000

(U) The Cost Effective Low Volume Nanofabrication 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 MEMs.

(U) Program Plans:

FY 2009 Plans:

- Evaluate 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.

	FY 2007	FY 2008	FY 2009
Technology for Ultra-High-Linearity Mixers	0.000	0.000	5.000

(U) The Technology for Ultra-High-Linearity Mixers program goal is to develop ultra-high-linearity electronic mixers to support the need of wideband high-dynamic-range receivers. To fully realize the capabilities of the ultra-high-linearity low-noise amplifiers (LNA) and ultra-high-dynamic-range analog-to-digital converters (ADCs) currently being developed under other DARPA programs, the dynamic range requirements

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through the receiver chain will need to be larger. Since the mixer is a critical part of the receiver and is located between the LNA and ADC, this challenging dynamic-range goal will require the output third intercept point of the mixer to be larger than +60 decibel milliwatt (dBm). This regime of linearity performance is well beyond current state-of-the-art. Although the linearity of the mixer usually increases with the power of the associated local oscillator, the projected power required to meet the +60dBm requirement will be impractical for most applications. Thus, this proposed project will focus on developing the necessary technologies to enable a mixer without an additional power penalty.

(U) Program Plans:
FY 2009 Plans:
- Develop scalable ultra-high speed gallium nitride (GaN) High Electron Mobility Transistor device technology.
- Develop ultra-high linearity mixer circuit architecture.
- Demonstrate integration technology for ultra-high-linearity mixer.

	FY 2007	FY 2008	FY 2009
Disruptive Manufacturing Technologies (DMT)	3.008	3.368	5.392

(U) The goal of the Disruptive Manufacturing Technologies (DMT) program is 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. The DMT program will merge Polystrata™ and GaN technologies to eliminate the need for monolithic microwave integrated circuits (MMICs). The direct product replacement transition candidate for this program is the TWT power amplifier output stage in the AN/ALE-55, Fiber Optic Towed Decoy for the Navy's new F/A-18 E/F Super Hornet, and the Air Force B1-B and F-15 platforms. It will be replaced with solid-state hybrid microwave integrate circuit (HyMIC) modules developed by merging Polystrata™ and gallium nitride (GaN) technologies. The result will be a 10x reduction in TWTA cost, equaling >$150M for the Integrated Defensive Electronic Countermeasures (IDECM) program, a joint Navy-Air Force program. Beyond developing a replacement for TWTAs, HyMIC technology promises to increase adoption of high performance MMW systems employing mature III-V technologies as well as advance earlier adoption of those using nascent III-V technologies.

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(U) Program Plans:

FY 2007 Accomplishments:
- Demonstrated integration of GaN transistors and passive elements with Polystrata™ waveguides.

FY 2008 Plans:
- Demonstrate flip chip mounting on Polystrata™ structures.
- Complete proof-of-concept GaN 20 watts module implemented with Polystrata™ technology, along with a passive element library to enable development of the 57 W GaN building block.

FY 2009 Plans:
- Demonstrate a form-fit-function 160 W GaN amplifier ready for insertion into the IDECM decoy module.

	FY 2007	FY 2008	FY 2009
Electronic Miniaturization	2.800	0.000	0.000

(U) This program developed advanced electronic miniaturization technologies.

(U) Program Plans:

FY 2007 Accomplishments:
- Developed novel techniques for miniaturization of electronic components.

	FY 2007	FY 2008	FY 2009
Ultra-Low Power Electronics for Special Purpose Computers*	1.000	1.040	0.000

*Formerly Enabling Obiquitous Computing through Nanoscale Ultra-Low Power Electronics.

(U) This program developed advanced computing technology utilizing very low power electronic devices.

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(U) Program Plans:

FY 2007 Accomplishments:

- Developed nanoscale low power electronics for defense applications.

FY 2008 Plans:

- Develop low power nanoscale electronics for special purpose computers.

	FY 2007	FY 2008	FY 2009
Computing and Nanoscale Electronic Processing	0.000	1.200	0.000

(U) The main objective of this program is to explore computing and nanoscale electronic processes.

(U) Program Plans:

FY 2008 Plans:

- Develop new applications for nanoscale electronics.

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

- Not Applicable.