RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE: February 2008
APPROPRIATION/BUDGET ACTIVITY: RDT&E, Defense-wide; BA2 Applied Research	R-1 ITEM NOMENCLATURE: Materials & Biological Technology; PE 0602715E

COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	270.513	301.741	285.264	257.799	256.392	273.508	263.600
Materials Processing Technology MBT-01	144.762	191.151	154.158	151.433	161.954	179.070	169.163
Biologically Based Materials and Devices MBT-02	125.751	110.590	131.106	106.366	94.438	94.438	94.437

(U) Mission Description:

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

(U) The major goal of the Materials Processing Technology project is to develop novel materials, materials processing techniques, mathematical models, and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling for improvements in logistics.

(U) The Biologically Based Materials and Devices Project acknowledges the growing and pervasive influence of the biological sciences on the development of new materials, devices and processes, as well as the commensurate influence of materials, physics and chemistry on new approaches to biology and biochemistry. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the development of biochemical materials to maintain performance, the use of biology's unique fabrication capabilities to produce structures that cannot be made any other way, the application of magnetic materials in biological applications, and the development of manufacturing tools that use biological components and processes for material synthesis. It also supports a major thrust that will revolutionize the development of prosthetics for the wounded soldier.

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

	FY 2007	FY 2008	FY 2009
Previous President's Budget	298.147	306.022	303.363
Current Budget	270.513	301.741	285.264
Total Adjustments	-27.634	-4.281	-18.099
Congressional program reductions	-20.000	-14.081	
Congressional increases	0.000	9.800	
Reprogrammings	0.000		
SBIR/STTR transfer	-7.634		

(U) Change Summary Explanation:

FY 2007	The decrease reflects the SBIR/STTR transfer and Section 8043 Rescission.
FY 2008	The decrease reflects a PE execution adjustment and reductions for Section 8097 Contractor Efficiencies and Section 8104 Economic Assumptions; offset by congressional adds for Economic Production of Coal to Liquid Fuel, Reduce Environmental Impact of Coal to Liquid Fuels, and Strategic Materials and Silicon Carbide Optics.
FY 2009	The decrease reflects the transition of the Prognosis Program to the U.S. Air Force and rephasing of several materials programs.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Materials Processing Technology MBT-01	144.762	191.151	154.158	151.433	161.954	179.070	169.163

(U) Mission Description:

(U) The major goal of the Materials Processing Technology project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced structural and functional materials and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of materials including: structural materials and devices, smart materials and actuators, functional materials and devices, and materials that are enabling improvements in logistics.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
Materials Processing and Manufacturing	11.710	14.999	14.000

(U) The Materials Processing and Manufacturing thrust is exploring new manufacturing and processing approaches that will dramatically lower the cost and decrease the time it takes for DoD systems to be fabricated. It will also develop approaches that yield new materials and materials capabilities that cannot be made through conventional processing approaches. Included are disruptive manufacturing approaches for raw materials and components.

(U) Program Plans:

FY 2007 Accomplishments:

- Established digital representation of microstructure across the nano-, micro- and meso-scales to effectively and quantitatively describe structures and features of interest.
- Developed data synthesis and management techniques for efficient information storage, manipulation and utilization by physics-based models.

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- Established protocol for reconstruction of digital microstructure at all appropriate length scales.
- Demonstrated carbon nanotube filaments from electrospun precursor polymer fibers.
- Demonstrated composite fibers incorporating carbon nanotubes in graphite derived via commercially scalable fiber production methodologies.
- Designed and built a maskless optical imaging system (MOIS) suitable for large area lithographic patterning of formulations used to make cores and shells for casting of internally cooled superalloy blades.
- Completed screening activities to determine the best candidate resin, fiber, and film adhesive to be used for out of the autoclave manufacturing of polymer matrix composites for aerospace applications.

FY 2008 Plans:

- Demonstrate capability to capture salient features of microstructure, convert data into functional entries for physics-based model parameters, and demonstrate active reconstruction of microstructure for visualization.
- Demonstrate integration with digital microstructural representation in order to illustrate dynamic effects on salient features in response to extrinsic stimuli.
- Demonstrate carbon fiber properties that are in excess of 1000 ksi in strength, 50 msi in modulus and 2% strain to failure.
- Design, build, and operate large area lithographic exposure machine subsystems to produce ceramic cores for casting of superalloy turbine blades.

FY 2009 Plans:

- Demonstrate integration with digital microstructural representation in order to identify critical features for design of material composition and processing to achieve microstructure for a set of desired properties.
- Demonstrate integration of physics-based predictive models of materials performance with digital microstructural representation.
- Demonstrate carbon fiber properties that are in excess of 1800 ksi in strength, 60 msi in modulus and 3% strain to failure.
- Demonstrate economical tooling for low volume production of polymer matrix composite (PMC) (10-25 units of a CH-47 helicopter ramp) that operates at less than 200 degrees Celsius cure temperature. Verify PMC subcomponent (containing critical details) meets static, fatigue, and destructive evaluations.

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	FY 2007	FY 2008	FY 2009
Structural Materials and Coatings*	11.550	11.800	8.137

*Previously this was part of Materials Processing and Manufacturing.

(U) The Structural Materials and Coatings thrust is exploring and developing new materials that will provide enhanced structural and/or surface properties for DoD applications. Included are approaches that avoid corrosion, provide superior strength at greatly reduced material density, provide the basis for a new generation of structural composite materials, and enable prolonged lifetimes for DoD systems and components.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated viability of the electrochemical reduction of TiO2 to titanium at a current efficiency greater than 80%.
- Entered into an agreement with industrial partner to scale-up the technology.
- Demonstrated coatings with outstanding corrosion resistance suitable for both Naval applications and long term radioactive storage capability.
- Demonstrated second generation amorphous metals with high damage tolerance while maintaining very high strength and hardness.
- Demonstrated that ultralight aluminum, calcium, magnesium alloys for space applications can be fabricated using conventional injection molding technologies.
- Demonstrated Al based alloys for turbine fan blade applications that promise increased performance and reduced fuel consumption.
- Demonstrated corrosion resistant material coatings and non-skid capability for naval combatant ships.

FY 2008 Plans:

- Develop process for large-scale Ti production.
- Perform structural test of unitized multifunctional panel to validate performance of thermal management and load carrying capability over the temperature range of -200 to +200F.
- Produce 1.5 sets of Al based amorphous turbine engine blades that meet print (dimensional) requirements.
- Demonstrate thermal spray technologies and processes at large-scale contractor facility on substrate materials.

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FY 2009 Plans:
- Demonstrate 10x improvement in fracture toughness for Fe based bulk metallic glasses.
- Certify high performance corrosion resistant materials (HPCRM) coatings for unrestricted use on Naval combatants.

	FY 2007	FY 2008	FY 2009
Multifunctional Materials and Structures	15.700	16.000	11.821

(U) The Multifunctional Materials and Structures thrust is developing materials and structures that are explicitly tailored for multiple functions and/or unique mechanical properties. This thrust also explores novel materials that are designed to adapt structural or functional properties to environmental and/or tactical threat conditions. Included in this thrust are efforts that will lower the weight and increase the performance of aircraft, enhance the efficiency of turbines, and improve the survivability of space structures.

(U) Program Plans:

FY 2007 Accomplishments:
- Demonstrated 2X surface hardness in alloy 718 using the low temperature colossal super saturation of Carbon in the atomic lattice.
- Demonstrated ability to control periodic nano features in alumina for warm forming of polymers.
- Designed evaporatively cooled blade configuration of very high thermal efficiency that if applied to current turbine engines would provide significant performance and/or specific fuel consumption benefits.
- Initiated fabrication of a complete set of turbine blades and modified a test bed engine to accept them for engine demonstration.
- Established proof-of-concept that incorporation of circulatory systems into materials can modulate electromagnetic, functional and mechanical properties.

FY 2008 Plans:
- Demonstrate superhydrophobic surfaces up to $1m^2$.
- Integrate solar power collection/thin film battery storage device with collection efficiencies greater than 20% and power output 100X that of state-of-the-art thin film batteries (5 in x 5 in minimum).
- Demonstrate cavitation resistant alloys for use on combat ship propulsors.
- Run test engine with evaporative cooled blades and quantify performance benefits.

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– Initiate development of material systems whose physical, chemical, electromagnetic, or mechanical properties can be modified upon command or in response to environmental stimuli.

FY 2009 Plans:

– Demonstrate functional prototype integrated flexible solar collection array/thin film battery (5 in x 5 in minimum).
– Demonstrate surface wave and power transmission control; point to point communications with less than 1 dB power loss over $1m^2$.
– Predict performance for an operational engine derived from the prototype unit.
– Develop prototype materials whose physical, chemical, electromagnetic, or mechanical properties can be modified upon command or in response to environmental stimuli.

	FY 2007	FY 2008	FY 2009
Materials for Force Protection*	12.123	23.219	18.500

*Previously this was part of Multifunctional Materials and Structures.

(U) The Materials for Force Protection thrust is developing novel materials and materials systems that will greatly enhance protection against ballistic, blast, and explosively formed projectile (EFP) threats. Included in this thrust are novel topological concepts as well as entirely new structural designs that will afford enhanced protection and functionality, at reduced weight and/or cost.

(U) Program Plans:

FY 2007 Accomplishments:

– Developed opaque armor solutions of classified capability.
– Developed a transparent spinel armor solution of increased capability that is significantly lower weight than current solutions.

FY 2008 Plans:

– Demonstrate ballistic performance with reduced weight as compared with rolled homogeneous armor areal density.
– Integrate high performance armor systems into vehicle platforms in collaboration with the U.S. Army and Marine Corps.
– Reduce the cost of hybrid composite armor systems with high throughput manufacturing techniques and by exploiting the benefits of commercial materials.
– Develop topological armor concepts for explosively formed projectile defeat.

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FY 2009 Plans:
- Develop lightweight armor systems to mitigate and defeat evolving threats, including explosively formed projectiles (EFPs).
- Evaluate topological armor concepts for protection against multiple threats.
- Optimize transparent armor for fragmentation and armor piercing threats.
- Integrate high performance armor systems with enhanced protection against evolving threats, including EFPs, into vehicle platforms in collaboration with the U.S. Army and Marine Corps.
- Demonstrate protective abilities of novel topological armor against explosively formed projectile threats.

	FY 2007	FY 2008	FY 2009
Prognosis	10.669	12.000	1.000

(U) The Prognosis thrust will demonstrate revolutionary, new concepts, physics-based models and advanced interrogation tools to assess damage evolution and predict future performance of the structural materials in defense platforms/systems. Included are demonstrations on Navy and Air Force aircraft structures, and engines for advanced jet aircraft and helicopters. Also included are sensor and model development required to support the damage prediction.

(U) Program Plans:

FY 2007 Accomplishments:
- Signed MOA between DARPA Director and Secretary of the Air Force transitioning engine system prognosis (ESP) module to the USAF.
- Conducted full scale testing on a modern gas turbine engine fan that includes prognosis sensors, transfer functions, and reasoners which will permit operating gas turbine engines with damaged fan and compressor blades to double the current damage limits thus significantly decreasing aircraft engine removal and repair requirements in operational units.
- Demonstrated effectiveness of prognosis technology in the H60 class of helicopter engines and in collaboration with the Navy transitioned elements of prognosis to the fleet.

FY 2008 Plans:
- Demonstrate Structurally Integrated Prognosis System (SIPS) on legacy airframes of EA6B and P3.

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– Demonstrate ESP system on the T700 helicopter engines with specific objective of real time "power available" notification to the pilot.

FY 2009 Plans:

– Complete and provide a functional ESP system applicable to the legacy (F100/F110) fleets that incorporates all physics- and data-driven models, exploits the available sensor packages, and incorporates all local and supervisory reasoners interfaced to the aircraft DEEC/MDEC for Oklahoma City Air Logistics Center (OC-ALC). Transition to Air Force Materiel Command.

	FY 2007	FY 2008	FY 2009
Materials for Initiation and Actuation*	4.561	7.234	5.929

*Previously this was part of Smart Materials.

(U) The Materials for Initiation and Actuation program explores and develops materials for initiation and propagation of mechanical and/or chemical effects. Included efforts are bio-inspired structures for meso-scale electrically initiated combustion, cyclic chemical reactions for communication, and high power, low volume, actuators required for high efficiency mobile platforms.

(U) Program Plans:

FY 2007 Accomplishments:

– Demonstrated 1,000 cycles for a combustion-recombinant based actuator.

FY 2008 Plans:

– Develop chemical systems that are able to encode arbitrary alphanumeric messages and transmit them as modulated optical signals at stand-off distances.
– Perform laboratory testing of modulated chemical systems to assess transmission properties including range.
– Demonstrate spanwise blade twisting on a representative rotor set.
– Fabricate, test, and assess silent maneuver capability of a nastic skin array on a scale model submersible.

FY 2009 Plans:

– Refine chemical systems to achieve 100-fold increase in transmission duration.

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- Engineer prototype chemical communications devices consisting of a disposable transmitter and a replicator device, with the form factor of a personal digital assistant, that translates messages into chemistry.
- Conduct rotor stand test of fully actuated 1/3 scale proprotor to demonstrate blade synchronization and lift improvement.
- Initiate development of a reactive structure in which the energetic and structural functions are integrated into the same material.

	FY 2007	FY 2008	FY 2009
Reconfigurable Structures	6.917	8.000	9.571

(U) In the Reconfigurable Structures thrust, new combinations of advanced materials, devices, and structural architectures are being developed to allow military platforms to morph or change shape to adapt optimally to changing mission requirements and unpredictable environments. This includes the demonstration of a morphing aircraft as well as new materials and devices that will enable the military to function more effectively in the urban theater of operations.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed first prototype of rapidly deployable and reversible, portable barriers to control enemy mobility in urban areas such as intersections, alleyways, doorways, etc.
- Developed model to analyze and reduce stresses due at the corners of contact pads to enable lower attachment pressures and increase adhesion to multiple surfaces.
- Determined the asperity (surface roughness) size distribution across multiple surfaces of interest and developed model to determine the most efficient pattern for asperity matching across said surfaces to ensure adhesion.
- Demonstrated >100 cycles of dry nanoadhesion to glass at approx 30 psi (normal).
- Developed, designed, and tested the actuators, materials, and control architectures necessary for achieving precise shape change in an airframe.
- Demonstrated capabilities of morphing aircraft technology in flight test achieving morphing initiated maneuver, improved turn rate, and improved climb rates between different morphed configurations.

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FY 2008 Plans:
- Develop soft chemically based materials with the ability to drastically change shape, reconfigure, and perform function.
- Engineer soft components from these materials that enable locomotion and size/shape morphing.
- Demonstrate adhesion repeated 100 times on glass, aluminum, and brick under both wet and dry conditions on a 4 inch by 4 inch pad.
- Determine proper climbing techniques via biomechanical analysis for maximum rate of climb, moving laterally, and descending using the required attachment-removal-reattachment kinematics.

FY 2009 Plans:
- Engineer materials and soft components into robotic architecture with the ability to locomote, traverse openings smaller than the characteristic dimension of the robot, reconstitute size/shape, and perform work using embedded payloads.
- Perform laboratory demonstrations of robot function.
- Refine and finalize pad designs for hands and feet based upon results of biomechanical analysis and human climbing trials.
- Demonstrate an equipped soldier (300 lb) scaling a series of 20 ft walls built from relevant materials.
- Develop a new class of synthetic materials whose structure/properties adapt to changing external conditions, using means intrinsic to the material.

	FY 2007	FY 2008	FY 2009
Functional Materials and Devices	14.500	13.399	16.200

(U) The goal of this thrust is to design material microstructures at the scale appropriate to exploit fundamental interactions with the environment in order to create materials with unique properties. Examples include engineered materials (metamaterials) that provide dramatically new electromagnetic behavior across the complete array of Defense applications. Other efforts include nanostructured materials to slow light, negative refractive index systems, and an array of other functional devices (antennas, dosimeters, etc.).

(U) Program Plans:

FY 2007 Accomplishments:
- Demonstrated a novel metamaterial dielectric with unprecedented properties for RF signal identification and tracking.
- Demonstrated novel thick film negative index materials at 20 GHz.

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- Demonstrated sub wavelength focusing at optical wavelengths.
- Demonstrated interleaving of 10 GigaBytes per second (GB/s) data streams using slow-light based tunable delay line.
- Demonstrated slowing of entire image using slow light tunable delay line.

FY 2008 Plans:

- Initiate parametric studies to define the accessible range of activity in surface/environment interactions.
- Design an optical negative index material based modulator for improved optical communications.
- Design a sub wavelength UHF antenna.
- Demonstrate delay of 10 GB/s data stream by more than 75 ns, and incorporate tunable delay into reconfigurable time-based multiplexer.

FY 2009 Plans:

- Design and develop modeling algorithms for surface/environment interactions.
- Demonstrate a low loss, negative index enabled optical modulator with enhanced performance for military communications.
- Demonstrate a subwavelength UHF antenna with enhanced performance for military radar and communication applications.
- Demonstrate delay of 40 GB/s data stream by more than 1 micro-second, and incorporate tunable delay into reconfigurable optical data buffer.
- Develop materials to create an underwater mission system that eliminates the need to carry a primary oxygen supply.

	FY 2007	FY 2008	FY 2009
Power Components*	7.332	12.000	10.500

*Previously this was part of Functional Materials and Devices and Materials for Power.

(U) This thrust explores and develops novel components for use in diverse power systems that will dramatically increase the overall energy efficiency, typically with a substantial savings of weight/volume as well as cost. Included in this thrust are new permanent magnetic materials with significantly higher magnetic strength and higher operating temperature for motors and generators, as well as high energy density capacitors. Hybrid superconducting/cryogenic components, which will provide a new paradigm for power electronics for the “all electric” platforms of the future. Materials technology is also being developed to enhance power conditioning for large power applications such as Navy ships.

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated a high throughput manufacturing process for 2nd generation high temperature superconducting wires with enhanced current carrying capacity at liquid nitrogen temperatures.
- Demonstrated nano-material architectures that are calculated to significantly improve the energy product of magnets, power density of batteries, and figure of merit for high temperature thermoelectrics.
- Demonstrated two optimized nano-phase mixed oxides for anodes in lithium ion batteries.

FY 2008 Plans:

- Determine magnetostatic coupling mechanisms in large grain (> 1 micron) nanocomposite magnets.
- Develop novel compaction methods for achieving high density bulk nanocomposite magnets with superior properties.
- Demonstrate a lightweight inductor based on newly developed 2nd generation high temperature superconducting wires.
- Develop model to predict performance of the all superconducting motor concept with stator windings fabricated from 2nd generation high temperature superconducting wire.
- Develop new dielectric materials with high permittivity, high breakdown strength and high temperature (>200deg C) and incorporate into high energy dense capacitor able to achieve 20J/cc and 100J.
- Develop nano-structured materials and demonstrate the ability to improve thermal electrics with >30% efficiencies, magnetics (30% improvements), and electrochemical (100% improvements) energy storage and conversion.

FY 2009 Plans:

- Develop a predictive modeling tool for the performance of magnetostatic coupled nanocomposite magnets.
- Verify the fidelity of the nanocomposite magnet modeling tool via experimentation.
- Evaluate the potential for cryogenic power electronics based on 2nd generation high temperature superconducting wires for reducing overall losses in Naval shipboard power systems.
- Innovatively package the 20J/cc dielectrics into capacitors with sensing capabilities to provide reliable high power capacitors of 20J/cc and 400J.
- Integrate nano-structured materials with high efficiencies and energy densities into DoD-relevant systems while maintaining the nano-structures of the materials thus increasing energy capabilities.

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	FY 2007	FY 2008	FY 2009
Novel Power Sources*	12.220	14.700	14.500

*Previously this was part of Materials for Power and Alternate Power Sources.

(U) The Novel Power Sources thrust will explore new materials solutions to enable power to be efficiently generated and controlled. This includes new materials concepts to increase the efficiency and robustness of portable fuel cells as well as the exploitation of nanotechnology to increase the efficiency and lower the weight of batteries. New materials and designs will also be applied to the development of novel mesoscale engines (e.g., Stirling, water lubricated steam engines) that will provide needed power on the battlefield. An additional focus is to develop materials to drastically improve the efficiency of low temperature thermoelectric components and develop these components into demonstration systems.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated concepts for highly power-dense, man-portable kilowatt generators that will reduce the logistics burden for the soldier in the field.
- Demonstrated a propane fueled 20 W solid oxide fuel cell capability with energy densities > 7x that of current military batteries.
- Demonstrated a portable JP-8 fueled Stirling engine generator.
- Demonstrated record breaking thermal to electric conversion efficiencies approaching 20%.
- Demonstrated record breaking thermal to electric power densities > 5 W/cm^2.
- Demonstrated novel fuel cell based on liquid tin anode for electrochemically converting JP-8 fuel to electricity.
- Developed a theoretical tool for predicting cathode chemistries with > 3x energy density compared to current batteries.
- Initiated new methods for high efficiency non-sacrificial catalysts to reduce carbon dioxide to carbon monoxide for conversion to liquid fuel.

FY 2008 Plans:

- Demonstrate the advantages of fuel cell and Stirling engine generators for enabling longer duration UAV, UGV, and soldier portable applications in relevant military environments.
- Demonstrate “proof of concept” for hybrid electronics enabled high efficiency, high density power electronics for military platforms.

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- Scale up current thermal to electric conversion generators to > 100 W.
- Scale up and integrate JP-8 fuel cell components into a 4 cell stack.
- Develop catalysts for reducing carbon dioxide with sunlight.
- Identify other chemical reactions necessary for liquid fuel systems.
- Design strategy for the conversion of carbon dioxide to JP-8.
- Demonstrate proof of concept for high energy density batteries using newly developed nanostructured cathode and anode materials.

FY 2009 Plans:

- Demonstrate high energy density power sources that enable UAV and UGV mission durations that are >5x longer than current state of the art batteries allow.
- Demonstrate a fully ruggedized (MIL-STD environmental factors) JP-8 fueled battery charger for next generation military rechargeable batteries.
- Provide a military relevant prototype demonstration of the weight and volume savings achievable using a hybrid approach for military efficiency power electronics.
- Conduct a full scale demonstration of a 1 kW or greater thermal to electric generator with record efficiencies and power densities.
- Demonstrate proof of concept for a novel fuel cell chemistry that operates at low to moderate temperatures but exhibits the higher power density, reduced balance of plant complexity, and fuel flexibility of higher temperature solid oxide fuel cells.
- Transition JP-8 fuel cell technology to Services for further development.
- Demonstrate 50% efficiency in the reduction of carbon dioxide to a carbon intermediate.
- Provide a full scale demonstration of a high energy density, high power density nanostructured battery.
- Investigate scaling of potential catalysis approaches for personal, small unit, and mobile power facility fuel cell applications.
- Optimize catalyst performance over a broad range of potential fuels including, but not limited to, ethanol, butanol, and JP-8.
- Develop second generation catalyst approaches and corresponding fuel cell designs to expand the range of operable fuels and scale down system size to personal or small unit scale.

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	FY 2007	FY 2008	FY 2009
Very High Efficiency Solar Cell (VHESC)*	8.000	17.500	21.000

*Previously this was part of Materials for Power.

(U) The objective of the Very High Efficiency Solar Cell (VHESC) program is to demonstrate at least 50% efficiency in an affordable, manufacturable photovoltaic (PV) device. This technology breakthrough will provide soldiers with portable power for electronic devices resulting in a dramatic reduction in the complex logistics associated with delivering batteries to troops in the field, while improving mission endurance and individual soldier agility.

(U) The program addresses all aspects of the high-efficiency PV problem including the development and analysis of high efficiency design concepts, the development of new and innovative components, materials, and processes necessary to achieve these concepts, and the development of scalable fabrication processes that are extensible to industrial manufacturing and an affordable product. Breakthrough results achieved in previous program phases including lateral architectures and non-imaging optical systems, high performance multi-band PV conversion, and ultra-low-cost PV materials fabrication processes have strongly narrowed the focus of the effort going forward. Future program phases will address both the technology development and manufacturing concept and engineering development necessary for the effective implementation of the VHESC technology in an affordable product. The key focus areas of these next two phases will be: 1) the system-integrated design optimization of the non-imaging lateral optics subsystem and the corresponding photovoltaic devices and 2) the development of high-volume cost-effective manufacturing engineering designs and processes for the subsequent future transition to affordable production.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated greater efficiency of solar cell optics and converter technologies in high, mid, and low energy photon environments.
- Developed novel concepts for extremely high efficient solar cells (>50%) and novel solar cell configurations for battlefield deployment.
- Demonstrated optical elements design with > 90% optical efficiency.
- Demonstrated solar cell device efficiency >40%.

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FY 2008 Plans:
- Demonstrate integrated prototype module > 40% efficiency.
- Demonstrate potential cost reduction technologies supporting cost scaling in large scale production.

FY 2009 Plans:
- Deliver initial product designs and production processes for >40% efficient modules.
- Demonstrate integrated system efficiency >50% in 10cm^2 prototypes.
- Deliver an initial integrated soldier systems device (e.g. flashlight or radio with integral solar cell).

	FY 2007	FY 2008	FY 2009
Alternate Power Sources	13.980	13.000	6.000

(U) The aim of the Alternate Power Sources thrust is to develop materials and technologies to utilize alternative power sources that have the potential to provide significant strategic and tactical advantages to the Department of Defense. The thrust is very diverse, and includes the development of diverse, portable power platforms that efficiently (>90%) utilize military waste materials (plastic and paper) for generation of electricity, as well as the development of agricultural plastics that are optimum for electricity generation in these platforms. An additional thrust aims to autonomously extract hydrocarbons such as methane hydrates from the continental shelves, using unmanned drilling and energy recovery vehicles.

(U) Program Plans:

FY 2007 Accomplishments:
- Completed independent evaluation of recently reported experimental protocol for achieving “excess heat” conditions in Pd cathodes loaded with deuterium.
- Integrated new battery and fuel cell chemistries and architectures to fabricate microbatteries with energy densities greater than 200 Wh/L, breaking current state-of-the-art energy densities in volumes smaller than 10 cubic millimeters.
- Completed design for neutron generator with a rate of 10 million per second in a pyroelectric crystal enabled-device.
- Demonstrated directional neutron generation in laboratory scale device.
- Demonstrated depolymerization of mixed plastic into simple hydrocarbon gases by supercritical water.

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- Demonstrated pilot-scale Mobile Integrated Sustainable Energy Recovery (MISER) process for converting waste to 5 kilowatts electric power.
- Demonstrated overall system efficiency of MISER process equal to 70%.
- Demonstrated lab-scale synthesis (0.1g/L/hr) of new bio-based monomer and conversion to high molecular weight polymer with high energy recoverability for future packaging applications.

FY 2008 Plans:

- Develop plan to reduce the volume of the packaged battery and fuel cell to 1 cubic millimeter, while maintaining an energy density of 200 Wh/L.
- Scale up 5 kW MISER process to 60 kW electric generator and demonstrate at a military base.
- Demonstrate efficiency of 90% in MISER system installation.
- Demonstrate use of mixed plastics and paper as fuel for MISER system.
- Improve synthesis (0.5g/L/hr) and polymerization processes for high energy recoverability polymers.
- Determine the correlation between excess heat observations and production of nuclear by-products.

FY 2009 Plans:

- Further improve packaging and architectures to reach final energy density goals of greater than 350 Wh/L, in a volume less than 1 cubic millimeter.
- Demonstrate conversion of bio-based monomer to polymer in 8 hours and conversion of polymer to bio-fuel in 24 hours.
- Demonstrate autonomous cutter head replacement and wellbore measurement for the extraction of hydrocarbons concept.
- Perform system energy analysis including modeling and assessment of scaling limits for the extraction of hydrocarbons concept.

	FY 2007	FY 2008	FY 2009
Biofuels*	3.000	6.500	8.000

*Previously this was part of Alternate Power Sources.

(U) The Biofuels program is exploring longer term, higher risk approaches to obtaining and using energy. A pathway to affordable self-sustainable agriculture-sourced production of an alternative to petroleum-derived JP-8 that will meet all DoD needs will be investigated. Initial efforts are focused on the conversion of crop oil triglycerides to JP-8. Additional efforts will expand the spectrum of convertible feedstocks to

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cellulosic, algal, and other similar materials, enabling a diversified feedstock portfolio that can meet the entire DoD need within a sustainable commercial framework. An important variant of this latter category is the development of man- and vehicle-portable technologies to produce substantial quantities of JP-8 and other useful liquid fuels from indigenously available or harvestable resources near desired locations worldwide.

(U) Program Plans:

FY 2007 Accomplishments:

- Selected a diverse set of technological development pathways to achieve a 60% (or greater) conversion efficiency, by energy content, of crop oil to JP-8 surrogate and elucidate a path to 90% conversion.
- Identified an alternative potential pathway for the production of affordable JP-8 fuel from the seed and grain husk remnants resulting from oil seed and grain seed processing.

FY 2008 Plans:

- Design, develop, and demonstrate a process pathway for >60% conversion (by energy) of crop oil to JP-8.
- Elucidate a path to 90% conversion of crop oil to JP-8.
- Demonstrate the scalability of production technologies for the affordable conversion of crop oil to JP-8 at <$5/gal cost.
- Identify and select technology pathways for the conversion of a broad diversity of cellulosic, algal, and other similar feedstocks to affordable bulk quantities of JP-8.
- Identify and select technology pathways for the development of man- and vehicle-portable systems capable of producing JP-8 and other useful liquid fuels from a broad diversity of feedstocks.

FY 2009 Plans:

- Demonstrate the conversion of cellulosic materials to JP-8 range alkanes with >30% efficiency (by energy).
- Identify a pathway for the conversion of cellulosic materials to JP-8 range alkanes with >50% efficiency (by energy).
- Explore the size and volume efficiency scaling relationships for various processing technologies for converting indigenous materials to JP-8 and other liquid fuels.
- Develop preliminary designs for vehicle-portable and man-portable liquid fuel production systems.

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	FY 2007	FY 2008	FY 2009
Long Duration Power Concepts	8.500	11.000	9.000

(U) The requirement for generating power over long duration missions proposes unique challenges in energy storage, power conditioning and overall integration. This thrust is exploring the breakthroughs in power generation needed for extremely long duration, unmanned applications including unmanned underwater vehicles (UUVs) and unmanned air vehicles (UAVs). These include energy storage approaches that are structurally efficient as well as energy efficient. It also includes approaches for efficiently removing the energy at rates commensurate with the high sprint power often required in these applications.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated an engineering concept based on solid oxide fuel cell and rechargeable batteries for enabling a 30 day large scale UUV mission.
- Demonstrated fuel cell with energy density required to achieve mission set.
- Demonstrated 3x enhancement of carbon fuel cell power output.
- Developed multifunctional material concept for UUV fuel storage.

FY 2008 Plans:

- Demonstrate breadboard UUV power system capable of enabling a 30 day large scale UUV mission.

FY 2009 Plans:

- Full scale laboratory demonstration of solid oxide fuel cell/battery power system for a 30 day large scale UUV mission.

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	FY 2007	FY 2008	FY 2009
Strategic Materials	4.000	5.000	0.000

(U) Program Plans:
FY 2007 Accomplishments:
- Developed reliable, robust, repeatable, and cost effective Chemical Vapor Composite (CVC) SiC manufacturing process for high tech military, space, and industrial applications.

FY 2008 Plans:
- Optimize the process for reliable, robust, repeatable, and cost effective CVC SiC manufacturing process for high tech military, space, and industrial applications.

	FY 2007	FY 2008	FY 2009
Economic Production of Coal-to-Liquid Fuels	0.000	2.400	0.000

(U) This program will research the economic production of converting coal fuels to liquid fuels.

(U) Program Plans:
FY 2008 Plans:
- Research the economic production of converting coal fuels to liquid fuels.

	FY 2007	FY 2008	FY 2009
Reduce Environmental Impact of Coal-to-Liquid Fuels	0.000	2.400	0.000

(U) This program will research ways to reduce the environmental impact of converting coal fuels to liquid fuels.

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(U) Program Plans:
FY 2008 Plans:
– Research ways to reduce the environmental impact of converting coal fuels to liquid fuels.

(U) Other Program Funding Summary Cost:

- Not Applicable.

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COST (In Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Biologically Based Materials and Devices MBT-02	125.751	110.590	131.106	106.366	94.438	94.438	94.437

(U) Mission Description:

(U) This project acknowledges the growing and pervasive influence of the biological sciences on the development of new DoD capabilities. This influence extends throughout the development of new materials, devices and processes, and relies on the integration of biological breakthroughs with those in engineering and the physical sciences. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the use of biology's unique fabrication capabilities to produce structures that cannot be made any other way, the application of magnetic materials in biological applications, and the development of manufacturing tools that use biological components and processes for materials synthesis. This project also includes major efforts aimed at integrating biological and digital sensing methodologies and maintaining human combat performance despite the extraordinary stressors of combat. Finally, this thrust will develop new diagnostics, therapeutics, and procedures to save lives on the battlefield, as well as restore full functional capabilities to combat amputees by developing a revolutionary upper limb prosthetic device.

(U) Program Accomplishments/Planned Programs:

	FY 2007	FY 2008	FY 2009
BioRobotics and BioMechanics*	25.000	7.000	1.000

*Formerly Bioinspired Locomotion and Sensing.

(U) The BioRobotics and BioMechanics thrust explores approaches to capture biological systems' ability to move and sense, and emulate these in man-made robotic or sensor systems. The effort includes providing robotics with the mobility required to provide support to soldiers in all terrains, including climbing. This thrust also includes efforts to develop bioinspired swimming aids that will increase the speed and reduce the metabolic costs for combat divers, and make current devices (fins) obsolete for most tactical scenarios.

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(U) Program Plans:

FY 2007 Accomplishments:

- Developed bioinspired flow sensors (based on fish lateral lines) with a velocity sensitivity 10x better than current state-of-the-art sensors.
- Demonstrated velocity sensitivity better than .01m/sec and an angular resolution of $<5^{o}$ (over 360^{o}).
- Completed modeling of the Melanophila beetles' infrared sensilla organ including photomechanics, microfluidics and microhydraulics.
- Designed, built and tested oscillating foil devices (OFDs), which decreased the metabolic cost of swimming 1km by 50%.
- Finalized the functional geometry of the OFD in a rebreather compatible configuration.
- Developed revolutionary processing approach for fabricating polymer gradient index (GRIN) lenses of almost any size. This technique allows the tailoring of the refractive index profiles in the radial direction as well as along the optical axis in a GRIN lens.
- Achieved GRIN lens Index variations of .12.
- Built and demonstrated a foveated vision system (120 degrees field of view) based on a new generation of high-birefringence liquid crystal (having an index change of >.6) spatial light modulator.
- Demonstrated tetrapod bio-inspired robot with dynamic stability over unplanned terrain including scree.
- Demonstrated carriage of >30kg load over unplanned terrain by tetrapod robot.
- Demonstrated vertical climbing bioinspired robot in both urban and forest environments.
- Signed transition MOA with USMC for tactical tetrapod robot.

FY 2008 Plans:

- Design folding OFDs with 0.5 ft^3 packed volume. Perform simulated missions with OFD devices with elements of the Army, Navy, and Marines. Fabrication of sixty OFD units followed by operational validation. Transition to the military user.
- Design and demonstrate a GRIN lens solution for a night vision system operating in the short wave infrared (SWIR) band.
- Design and demonstrate a non-mechanical (adaptive optical) zoom riflescope based on viscous optical polymer lenses. Zoom riflescope will operate between 1x, 2x, 4x and 10x at the push of a button.
- Demonstrate mobility and range capability in a militarily relevant environment by traversing five miles of wooded terrain while following a human lead.
- Demonstrate dynamic climbing on vertical terrestrial features.

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FY 2009 Plans:
- Deliver fully integrated GRIN optical system to the Army Night Vision Laboratory to be incorporated into a light-weight, high-performance SWIR imaging system.
- Deliver and qualify (MilSpec shock/temperature) a non-mechanical zoom riflescope (1x through 10x) to the Army for field evaluation.

	FY 2007	FY 2008	FY 2009
Bioderived Materials	9.856	1.000	0.000

(U) The Bioderived Materials thrust explores the use of biological materials to support diverse Defense missions and/or technologies that enhance the capability of military biological platforms. Examples include the direct use of biological systems (e.g., plants) as sensors or antennas, as well as exploiting the work and energy harvesting capabilities of biological motors. Additional efforts provide sensor, localization, and communication technologies in direct support of military operations.

(U) Program Plans:

FY2007 Accomplishments:
- Demonstrated the utility of biomolecular motors for DNA transcription.
- Investigated the importance of quantum effects in biomotor function, performance and efficiency.
- Developed a biologically integrated stealthy platform for visual and auditory surveillance capabilities.

FY 2008 Plans:
- Demonstrate training of biological platform integrated with GPS, visual and auditory surveillance, in an urban-based environment.

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	FY 2007	FY 2008	FY 2009
Bioinspired Sensors*	9.000	11.500	12.900

*Previously part of Bioderived Materials.

(U) The Bioinspired Sensors thrust explores the application of biomimetic principles to materials and devices of interest to the DoD. Specifically, the unique characteristics of biologically derived material and devices will be exploited through understanding, control and emulation of the structure and chemistry of the interface between man-made and biotic materials. This includes an effort to understand the mammalian olfactory system and develop a system that performs equal to or better than a canine, in distance and level of chemical detection. Biological hearing systems also provide localization accuracy much better than predicted by simple array theory. Such systems use complex interactions between reflections off the outer ear and finely tuned neural patterns that provide exquisite localization and sensitivity. This effort includes a program to mimic similar reflections and signal processing approaches suitable for small UAVs.

(U) Program Plans:

FY 2007 Accomplishments:

- Initiated a series of bioinspired materials and sensor (e.g., visual, auditory, olfactory, gustatory and tactile) studies to examine unique characteristics/signatures.
- Investigated the applications to improve current sensor technologies, such as:
  - -- Approaches for utilizing bio-derived components from the mammalian olfactory system for the design of novel chemo-sensing systems.
  - -- Prototype vision sensors based on the properties of the mammalian retina for the creation of high dynamic range sensor capabilities, and tactile sensors for novel situational awareness in robotic platforms.

FY 2008 Plans:

- Develop components for a sensitive, but flexible olfactory system built from and inspired by the structure and components of the mammalian olfactory system.
- Develop methods for high throughput generation of odorant molecules of interest and stable expression of receptor proteins in a cell-based system.

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- Complete design review of prototype olfaction system, for a small number of candidate odorant molecules, using cell-based detection.
- Explore the fundamental interaction of loading metals into plants and elevating their conductive properties through injectable solutions.

FY 2009 Plans:

- Develop brassboard system, with emphasis on synthetic cell or non-cellular expression (chip) for detection of relevant odorant molecules.
- Demonstrate rapid production and detection of new odorant molecule not previously expressed in the synthetic system.
- Exploit increased knowledge in biologic sensing architectures to determine relevant opportunities for improved RF sensing techniques.
- Develop new signal processing and waveform design approaches to facilitate improved sensitivity and localization accuracy with less weight and power.
- Study plant morphologies that will produce useful transmit and receive capabilities in a plant antenna.

	FY 2007	FY 2008	FY 2009
Maintaining Combat Performance	11.700	6.500	8.500

(U) The Maintaining Combat Performance thrust utilizes breakthroughs in biology and physiology to sustain the peak physical and cognitive performance of warfighters operating in extreme conditions. Today, warfighters must accomplish their missions despite extraordinary physiologic stress. Examples of these stressors include extremes of temperature (-20°F to 125°F), oxygen deficiency in mountains, personal loads in excess of 100 lbs, dehydration, psychological stress, and even performance of life-sustaining maneuvers following combat injury. Not only must troops maintain optimum physical performance, but also peak cognitive performance, which includes the entire spectrum from personal navigation and target recognition, to complex command and control decisions, and intelligence synthesis. The Maintaining Combat Performance thrust leverages breakthroughs in diverse scientific fields in order to mitigate the effects of harsh combat environments. For example, understanding the natural mechanisms for core body temperature regulation in hibernating mammals has led to a novel, practical approach for soldier cooling, which is now being evaluated by troops in the far forward combat areas. Other examples include fundamental research elucidating the biological mechanisms of

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adaptation to extreme altitude, the molecular correlates of muscle fatigue and psychological stress, and natural resistance to disease through dietary nutrients.

(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated a safe, natural dietary supplement that prevented post-stress viral illness in humans.
- Demonstrated a novel ketone-based dietary fat substitute that prevents fatigue in experimental models.
- Identified the biochemical mechanism of skeletal muscle fatigue.
- Developed an understanding of the biochemical and physiological causes of decreased cognitive performance during sleep deprivation through studying animal model systems, synaptic function, and transcranial magnetic stimulation (TMS).
- Validated approaches for natural interventions and other concepts that restore the cognitive performance capabilities of warfighters during extended periods of sleep deprivation and stress.

FY 2008 Plans:

- Establish biologic mechanism for illness prevention by Quercetin.
- Complete pharmacokinetic and pharmacodynamic studies in humans.
- Complete toxicology evaluation of ketone-based dietary fat substitute.
- Develop a human formulation of ketone-based diet and demonstrate tolerability in humans.
- Implement prototype hand cooling device for light armored vehicles.
- Investigate approaches for mitigating the effects of disrupted circadian cycles including the use of targeted napping, sound or stimulation enhanced slow wave sleep, light modulation and other restorative techniques.
- Identify novel methodologies to reduce fatigue in sleep deprived conditions through brief, restorative sleep and sleep-like experiences.
- Identify genetic indicators of acute mountain sickness and develop approaches to improve cardio-pulmonary function at high altitude.
- Demonstrate high altitude acclimation can be induced by an effector treatment.
- Demonstrate a >40% improvement from preconditioning prior to high altitude exposure in experimental animals.
- Identify ≥ 2 novel biochemical pathways adversely affected by physiological and/or psychological stress.

FY 2009 Plans:

- Demonstrate performance benefits of ketone-based supplement in humans.

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- Develop and test hand-based warming device on SEAL Delivery Vehicles.
- Develop and demonstrate a selective stabilizer of the skeletal muscle sarcoplasmic reticulum calcium channel.
- Demonstrate the direct cognitive benefit of fatigue reduction methodologies on operational task measures.
- Develop prototype technologies that enable operators to experience restorative sleep at any point in their circadian rhythm in the deployed environment.
- Determine the effects of nitric oxide on altitude acclimatization and methods to minimize acute mountain sickness.
- Identify countermeasures that normalize stress-induced biochemical changes.
- Demonstrate functional improvement in experimental models of stress.

	FY 2007	FY 2008	FY 2009
Cognitive Technology Threat Warning System (CT2WS)*	0.000	8.600	15.800

*Previously part of Maintaining Combat Performance.

(U) Recent advances in computational and neural sciences indicate it is possible to push the visual threat detection envelope to enable more response choices for our soldiers than ever before. The objective of the Cognitive Technology Threat Warning System (CT2WS) program is to drive a breakthrough in soldier-portable visual threat warning devices by leveraging discoveries in the disparate technology areas of flat-field, wide-angle optics, large pixel-count digital imagers, visual processing pathways, neurally based target detection signatures and ultra-low power analog-digital hybrid signal processing electronics. This program will lead to the development of prototype soldier-portable digital imaging threat queuing systems capable of effective detection ranges of 1-10 km against dismounts and vehicles. Simultaneously, the system will survey a 120-degree or greater field of view, enabling the warfighter to detect, decide and act on the most advantageous timeline in complex operational environments.

(U) Program Plans:

FY 2008 Plans:

- Initiate system-level preliminary design of a prototype soldier-portable digital imaging visual threat cueing system capable of improving current effective detection ranges while simultaneously surveying wide field of view.

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- Evaluate methodologies for inclusion of wide angle optics, large pixel count digital imagers, cognitive visual processing algorithms, brain-derived target detection signatures and low power analog-digital hybrid electronics.
- Demonstrate single path (20° x 20°) advanced optics on a breadboard system in a field environment consistent with objective performance and package volume.
- Demonstrate composite software system capable of high fidelity threat detection with extremely low false alarm rates.

FY 2009 Plans:

- Develop integrated brassboard designs consistent with desired threat cueing performance with an increased field of view of 120° x 20° while maintaining size, weight and power constraints.
- Demonstrate visual/cognitive algorithm performance for threat detection on operationally significant image streams with probability of detection (>.98) and false alarm rates (<10) in less than thirty seconds of scan time.
- Complete critical design review of bench-integrated prototype system evaluations that demonstrate the capability of the design to meet the objective system program metrics.
- Evaluate device packaging approaches with the knowledge of ruggedization and robustness required for soldier-portable tactical electronic devices.

	FY 2007	FY 2008	FY 2009
Neovision2*	0.000	6.000	9.000

*Previously part of Maintaining Combat Performance.

(U) Biological vision systems have the exquisite ability to recognize, categorize, and learn new objects in fractions of a second. While animals and humans accomplish this seemingly effortlessly and constantly, computational vision systems have, to date, been unable to replicate this feat of biology. The Neovision2 program is pursuing an integrated approach to developing an advanced object recognition capability based on the visual pathways in the mammalian brain. Specifically, this program will develop a cognitive sensor technology with limited size, weight, and power that transforms data from an imaging sensor suite into communicable knowledge for mobile, autonomous surveillance systems. To achieve the vision, the program will utilize advanced device design, signal processing and mathematical techniques across multiple brain regions to revolutionize the field and create a neuromorphic vision system. This effort originated in PE 0601101E, Project BLS-01.

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(U) Program Plans:

FY 2008 Plans:

- Develop, fabricate and complete functional test of a neuromorphic application specific integrated circuit (ASIC) for emulation of mammalian visual pathway functionalities.
- Initiate scaling studies for design of a complete system prototype for biological visual pathway capabilities.
- Demonstrate advanced algorithms for visual pathway functionality (saccade, foveate and basic object recognition) on the ASIC and validate using topological analysis techniques.

FY 2009 Plans:

- Demonstrate a complete breadboard visual pathway emulation of saccade, foveation and object recognition with visual inputs, neuromorphic processing and natural language outputs in real time.
- Design a second generation application specific integrated circuit (ASIC) with increased functionality for the emulation of all nodes within the mammalian visual pathway (retina through higher cortex).
- Incorporate further refinements and developments of visual pathway algorithms and neuromorphic hardware into brassboard design for production and testing.

	FY 2007	FY 2008	FY 2009
Tactical Biomedical Technologies	19.895	16.950	18.756

(U) The Tactical Biomedical Technologies thrust will develop new approaches to deliver life-saving medical care on the battlefield, as well as novel technologies for reconstruction and rehabilitation of severely injured warfighters. Implicit in this thrust is the fact that there are unique, warfighter-specific challenges in acute and chronic treatment that are not addressed by civilian research and development. Today, more than half of American battlefield fatalities are due to hemorrhage, particularly due to improvised explosive devices (IEDs). To prevent these deaths, there is an urgent need for technologies that enable relatively unskilled personnel (battlefield medics) to diagnose and treat injuries, including the ability to locate and coagulate non-compressible deep bleeders in the thorax or abdomen. Other critical needs stem from the fact that warfighters are frequently victims of blasts, causing patterns of brain, burn, and orthopedic injuries not seen in civilian medical practice. As such, there is a unique military need to develop systems for pain control that are safe even in medically unmonitored environments, such as an active battlefield.

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Once lives are saved, there is an unmet need for new methods to restore function, for example, by restoring long segments of bone that were lost due to blast fragmentation. Development of a transportable magnetic resonance imager (MRI) that is an order of magnitude smaller in volume and weight than current technologies will greatly improve battlefield care. The results of this program will greatly enhance our ability to save lives on the battlefield and provide restoration of normal function to survivors.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed an ultrasound transducer cuff and modeled device performance and biophysical parameters.
- Demonstrated ultrasound detection, localization and coagulation of a simulated deep bleeder in an *in-vitro* testbed.
- Down selected approaches for biomarker control of drug release.
- Manufactured prototype simplified automated ventilator portable ventilators in order to provide emergency respiratory support to far forward personnel.
- Miniaturized first generation portable ventilators and implemented autonomous flow control; extended duty-cycle and improved ease of use.
- Demonstrated 75% group survival without fluid resuscitation after 60% total blood volume hemorrhage.

FY 2008 Plans:

- Develop and test algorithms for bleeder detection, localization, coagulation, and cuff control; integrate into a complete system.
- Conduct in vivo and in vitro experiments to determine the effect of physiological variables on the deep bleeder acoustic coagulation (DBAC) algorithm.
- Demonstrate efficacy of freeze-dried platelet hemostatic agent in pre-clinical models.
- In collaboration with the Navy, conduct clinical studies of freeze-dried platelet in humans.
- Demonstrate an in vitro delivery system that releases a therapeutic dose of a pain drug based on a chosen biological signal and that the release of the drug can be “shut off” when a biomarker for toxic effect is present.
- Initiate in vivo studies of the drug delivery system in live experimental models.
- Finalize good laboratory practices models required for animal rule approval by the FDA.
- Complete studies and reports required for pre-investigational new drug evaluations.
- Determine optimum contrast mechanisms for very low field MRI brain images.

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– Determine method to assess intra-cranial pressure using MRI system.

FY 2009 Plans:

– Develop a fieldable prototype DBAC system that is automated and operates on batteries.
– Demonstrate DBAC system is capable of detecting and localizing clinically significant bleeder size, tracking the movement of the site of bleeding despite patient movement, coagulating the bleeder, and determining completion of coagulation without a human decision maker in the loop.
– Demonstrate performance of pharmaceutical delivery system with additional class of drug(s).
– Demonstrate initiation of the full tissue repair process after loss of a multi-tissue structure in a mammal.
– Develop target product profile for clinical transition of injury repair therapeutics.
– Demonstrate a sprayable nano-clot technology with an in vitro burst pressure greater than 95mm Hg without heat generation of greater than 5°C.
– Conduct final review of freeze-dried platelet product and transition to Army and Navy-sponsored clinical trials.
– Design low magnetic field MRI system capable of producing diagnostic-quality brain image.
– Demonstrate efficacy of "surviving blood loss" therapies in a Good Laboratory Practices (GLP) animal model.

	FY 2007	FY 2008	FY 2009
Trauma Pod*	6.000	8.500	10.500

*Previously part of Tactical Biomedical Technologies.

(U) New approaches are necessary to deliver life-saving medical care on the battlefield. Research has demonstrated that several functions that currently take place in an operating room can be automated, such as tool and supply handling. Furthermore, these functions can be conducted faster and more effectively by autonomous machines making it possible to move these functions onto the battlefield. Developing the capability to perform autonomous diagnosis will assist the medic in determining the type and extent of the injury. Innovative procedure modules, imaging and surgical techniques, and a portable tactical platform will allow patient stabilization and provide precious additional time for transport to the combat support hospital.

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(U) Program Plans:

FY 2007 Accomplishments:

- Performed computed tomography scan on human phantom mounted on a life support for trauma and transport stretcher.
- Demonstrated remote surgery on a surgical mannequin through robotic assistance.

FY 2008 Plans:

- Develop and test additional, fully automated surgical techniques including opening of an airway and insertion of an IV.
- Design integrated system capable of treating pneumothorax, internal hemorrhage, and head trauma.
- Demonstrate proof of principle imaging and surgical techniques on human phantoms and animal models.

FY 2009 Plans:

- Integrate imaging and surgical modules into a portable tactical platform and test overall system.
- Demonstrate imaging and automated imaging diagnosis of a tension pneumothorax, intracerebral bleeding, abdominal bleeding, and retroperitoneal bleeding in an animal model.
- Demonstrate surgical techniques of an airway on an anatomical model, and insertion of an IV, relief of tension pneumothorax, and control of internal bleeding on an animal model.
- Demonstrate scalability of system.

	FY 2007	FY 2008	FY 2009
Biological Interfaces*	0.000	2.500	5.000

*Previously part of Tactical Biomedical Technologies.

(U) This thrust area explores and develops biological interfaces between biotic and abiotic materials. Examples include infection prevention/sterilization at the interface between skin and a battlefield medical device (such as a central intraveneous catheter) as well as enhancing the rehabilitation/recovery effectiveness of interfaces between bone and orthopedic stabilization devices.

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(U) Program Plans:

FY 2008 Plans:

- Demonstrate reliable plasma-initiated million-fold reduction in bacterial count and 99.9% inactivation of bacterial spore population on artificial or animal skin surfaces.
- Determine biochemical variables that accelerate bone growth to integrate with mechanical factors.

FY 2009 Plans:

- Design and construct plasma-based catheter capable of bacterial and spore population reduction.
- Determine appropriate control laws for osseous distraction rates and timing based upon the measured quantities.

	FY 2007	FY 2008	FY 2009
Neuroscience Technologies*	5.300	9.500	12.000

*Previously part of Maintaining Combat Performance.

(U) The Neuroscience Technologies thrust leverages recent advances in neurophysiology, neuro-imaging, cognitive science and molecular biology to sustain and protect the cognitive functioning of the warfighter faced with challenging operational conditions. Warfighters experience a wide variety of operational stresses, both mental and physical, that degrade critical cognitive functions such as memory, learning and decision making. Currently, the long-term impact of these stressors on the brain is unknown, both at the molecular and behavioral level. This thrust area will utilize modern neuroscientific techniques to develop quantitative models of this impact and explore mechanisms to protect and restore cognitive functioning following operational stressors. For example, molecular targets for the restoration of long term memory using micro-ribonucleic acids (mi-RNA) will be tested in animal models for their efficacy following stress and training. This project will also investigate the integration of recently-characterized properties of human brain function and real-time signal processing to enable rapid triage of target-containing imagery. This thrust area will have far-reaching implications for both current and future military operations, with the potential to protect warfighter cognitive performance both prior to and during deployment.

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(U) Program Plans:

FY 2007 Accomplishments:

- Demonstrated that neural signals can be used to significantly (300-500%) improve throughput in visual analysis tasks such as imagery analysis, as compared to using an individual's visuomotor transformation (i.e., movement) based response.
- Identified robust neural signatures for visually salient objects in operationally relevant imagery.

FY 2008 Plans:

- Demonstrate a 10x improvement in long term memory performance thirty days after training, using short nucleotide sequences administered in a single animal model prior to training.
- Develop a comprehensive quantitative description of the impact stress has on the brain, including neurophysiological, cognitive and behavioral measures. This includes understanding the processes by which certain individuals are resilient to the negative effects of stress, understanding how to prevent deleterious effects of stress exposure without blocking the biological and behavioral responses necessary for survival.
- Develop both task-specific and task-independent methods and strategies for neurophysiology-based learning acceleration applicable across multiple domains.
- Determine the stability of neural signatures in complex imagery conditions, including imagery sources and target types.
- Initiate controlled operational tests to demonstrate utility of neural signatures in imagery analysis environment to motivate potential transition interest.

FY 2009 Plans:

- Evaluate delivery methods of mixtures of short nucleotide sequences for long-term memory enhancement and demonstrate a 10-fold enhancement in long-term memory with single and multiple training episodes in two animal models for >30 days.
- Demonstrate the elimination of a deleterious stress response in the mammalian brain through pre-treatment with either behavioral training or pharmacologic administration without negatively impacting normal memory and brain function.
- Demonstrate learning acceleration techniques feasible for use across a broad range of individuals and explore the potential for group/team learning paradigms for increased quantity of expertise production.
- Demonstrate significant increase in imagery throughput and analytic product generation on specific operational tasks.
- Develop prototype systems that utilize neural signatures to speed analysis and improve quality and accuracy of imagery exploitation.

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– Initiate transition of technologies and methodologies to operational use, while validating utility of neural signature inputs into imagery workflow.

	FY 2007	FY 2008	FY 2009
Bio-Magnetic Interfacing Concepts (BioMagnetICs) Materials	4.000	0.000	0.000

(U) The Bio-Magnetic Interfacing Concepts (BioMagnetICs) Materials program developed and demonstrated novel capabilities for integrating nanomagnetics with biology and demonstrated the advantages of magnetics as a powerful new transduction mechanism for detecting, manipulating, and controlling biological function in single cells and biomolecules. The state-of-the-art research "tools" that have allowed researchers to observe the most fundamental units of biology (cells, DNA, proteins, etc.) do not possess the resolution, precision, or high throughput capacity to enable manipulation and/or functional control of large numbers of cells and biomolecules. Such a capability would have a pervasive and paradigm shifting impact on future military and civilian applications of biotechnology including chem-bio detection, therapeutics, and medical diagnostics. Nanoscale magnetics offers the promise of a robust, non-invasive, non-destructive, multiplexing, and high throughput interface that is compatible with the nanometer scale at which the biochemistry of cellular function exists.

(U) Program Plans:

FY 2007 Accomplishments:

– Demonstrated proof of concept for novel magnetics-based approaches to therapeutics and diagnostics for military personnel.
– Demonstrated proof of concept for portable, magnetics-based DNA and biochemical sensors.
– Demonstrated proof of concept for high sensitivity magnetics based biosensor array and transitioned to the Defense Threat Reduction Agency.

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	FY 2007	FY 2008	FY 2009
Military Medical Imaging*	7.500	6.040	9.000

*Previously part of Tactical Biomedical Technologies.

(U) The Military Medical Imaging thrust will develop medical imaging capabilities to support military missions and operations. Examples include novel technologies to miniaturize and enhance the capabilities and speed of CAT scanners and to develop non-invasive imaging modalities for use by medics. The emergence of advanced medical imaging allows us to appreciate newly recognized physical properties of biological tissue, or metabolic pathway, or physiological function in order to map it into an image of diagnostic utility and performance. This need is ever increasing as we seek to better understand anatomical, functional and cellular level interactions. The advanced development of these tools will provide a formidable arsenal of diagnostic tools for warfighter performance and care.

(U) Program Plans:

FY 2007 Accomplishments:

- Determined cause of fatal injuries and provided assessments of vulnerabilities and recommendations for enhancements to current protective gear.
- Validated virtual data with data from actual procedures for virtual autopsy.
- Initiated development of relational database for image queries for virtual autopsy.
- Completed development of a new advanced X-ray detector (Pixel Irradiated Contact (PIC)) which provided X-ray detection at quantum-limited signal-to-noise ratios over a thousandfold dynamic range.
- Built low power, demountable X-ray tube source.
- Demonstrated 3x improvement in photon production compared to conventional source.
- Demonstrated 5x improvement in X-ray vertex angle.
- X-ray source provided 2x yield, cone beam uniformity and 3.75x resolution in z dimension.

FY 2008 Plans:

- Incorporate rapid mission rehearsal thrust technologies with computer-aided forensic methods into after-action review to aid in reconstructing incidents from existing data.

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– Complete development of a new transmission anode X-ray source having 2.5 times higher yield and efficiency than conventional reflection anode X-ray tubes and a 40 degree vertex angle.

FY 2009 Plans:

– Demonstrate that an incident can be fully reverted to initial conditions using only injury and vehicle data.
– Utilize reconstructed scenarios for assessment of "lessons learned" and to gain immediate and relevant tactical battlefield knowledge.
– Develop a new dual-energy transmission anode X-ray source enabling dual-energy, digital-subtraction contrast imaging specifically targeting the detection of occult bleeding in battlefield casualties.

	FY 2007	FY 2008	FY 2009
Revolutionizing Prosthetics	25.000	23.500	24.650

(U) The goal of this thrust is to radically improve the state of the art for upper limb prosthetics, moving them from crude devices with minimal capabilities to fully integrated, fully functional limb replacements. Current prosthetic technology generally provides only gross motor functions, with very crude approaches to control. This makes it difficult for wounded soldiers to return to military service. The advances required to provide fully functional limb replacements will be achieved by an aggressive, milestone driven program combining the talents of scientists from diverse areas including: medicine, neuroscience, orthopedics, engineering, materials science, control and information theory, mathematics, power, manufacturing, rehabilitation, psychology and training. The results of this program will radically improve the ability of combat amputees to return to normal function.

(U) Program Plans:

FY 2007 Accomplishments:

– Constructed and tested three upper extremity limb prototypes incorporating features of advanced control, sensory feedback, and high degrees of articulation.
– Developed control methods using brain/neural activity as well as methods based on natural body movements supplemented by residual limb control.
– Began clinical testing of prototype limbs with amputee populations through surgical and non-surgical control methods.

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FY 2008 Plans:
- Perform testing and evaluation required for initiation of clinical trials.
- Design and manufacture prototype limb including biomimetic articulation, longevity of power consumption, and strength and weight which emulate form, function, and response of natural biological limbs.
- Develop and demonstrate a clinical prototype virtual integration environment.
- Initiate clinical testing of initial limb prototype in combat amputees at military medical centers.
- Develop strategies and technologies for commercial manufacture.

FY 2009 Plans:
- Integrate sensory feedback into prosthetic devices.
- Evaluate sensory feedback in patients with targeted neural re-implantation.
- Complete design of chip for transmission of central nervous system motor signals.
- Evaluate chip in experimental models.
- Demonstrate the ability to implement brain/neural control with sensor feedback in a control architecture that combines the kinetics and mechanics (degrees of freedom) of natural movement, including the realization of proprioception and reflex.
- Develop clinical protocol for testing of four-year prosthetic devices at military medical centers.
- Initiate manufacture plan consistent with Good Manufacturing Practices (GMP).

	FY 2007	FY 2008	FY 2009
Biodemilitarization of Munitions	0.000	3.000	4.000

(U) Based on results from the External Protection Program in PE 0602383E, Project BW-01, the Biodemilitarization of Munitions program will develop a system for rapid, safe, and effective inactivation of explosive munitions stockpiles in place. If these stockpiles can be removed, the raw materials for constructing improvised explosive devices will be greatly reduced. Chemical and biological technologies and control processes will be developed that rapidly perforate munition casings and alter the explosive fill. The perforation and explosive alteration technologies will be integrated into a fieldable system and tested against munitions stockpiles.

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(U) Program Plans:

FY 2008 Plans:

- Investigate technologies for rapidly perforating diverse types of munitions casings.
- Develop mathematical models that describe the perforation and inactivation technologies.
- Investigate technologies for rapidly inactivating diverse types of explosive fill.

FY 2009 Plans:

- Test system against explosive munitions with 155 mm projectiles.
- Develop prototype fieldable system.
- Integrate technologies into a prototype system.
- Test system against munitions stockpiles.

	FY 2007	FY 2008	FY 2009
Bio-Fabrication (B-FAB)	2.500	0.000	0.000

(U) The Bio-Fabrication (B-FAB) program demonstrated the feasibility of using biochemical processes as a new nanofabrication toolset to synthesize and manufacture chemicals, materials, and devices of high value to the DoD. Such approaches would be useful as part of the nanostructure for highly efficient solar cells. Other targets for demonstration within this program included scalable technologies for opto-electronic materials and devices, mechanical materials, and site-directed-synthesis.

(U) Program Plans:

FY 2007 Accomplishments:

- Developed bio-enabled routes for the fabrication of relevant electronic, optical, or structural materials.
- Demonstrated the essential capacity for the fabrication of the materials at the scale of interest (2-20nm range control).
- Demonstrated the capability to produce bio-fabricated materials with chemically and spatially modulated properties.
- Designed, developed, and integrated bio-fabricated optical devices with improved cost characteristics.

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(U) Other Program Funding Summary Cost:

- Not Applicable.