# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R2 Exhibit)

**February 2005**

BUDGET ACTIVITY
**2 - Applied Research**

PE NUMBER AND TITLE
**0602105A - MATERIALS TECHNOLOGY**

| COST (In Thousands) | | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate |
|---|---|---|---|---|---|---|---|---|---|
| | Total Program Element (PE) Cost | 40043 | 50788 | 17559 | 18236 | 19241 | 19590 | 19868 | 20128 |
| H7B | ADVANCED MATERIALS INITIATIVES (CA) | 25420 | 35758 | 0 | 0 | 0 | 0 | 0 | 0 |
| H7G | NANOMATERIALS APPLIED RESEARCH | 0 | 4555 | 5006 | 5193 | 5323 | 5469 | 5577 | 5688 |
| H84 | MATERIALS | 14623 | 10475 | 12553 | 13043 | 13918 | 14121 | 14291 | 14440 |

**A. Mission Description and Budget Item Justification:** This program element (PE) researches and evaluates materials technologies for armor and armaments that will significantly enhance the survivability and lethality of Future Combat Systems (FCS) and Future Force systems and, where feasible, can be exploited to enhance Current Force capabilities. The PE builds on the materials research transitioned from PE0601102 (Defense Research Sciences) H42 (Materials and Mechanics) and applies it to specific Army platforms and the individual soldier. Project H84 is directed toward developing materials technology that contributes to making our heavy forces lighter and more deployable, and our light forces more lethal and survivable. It provides the technology base required for solving materials-related problems in individual soldier support equipment, armor, armaments, aircraft, ground and combat vehicles and combat support. Project H7G funds the collaborative research efforts in nanomaterials technology between the ARL and the Institute for Soldier Nanotechnologies (ISN) at the Massachusetts Institute for Technology, MA and the ISN industry partners. The effort is focused specifically on the improvement in individual soldier protection. Project H7B funds Congressional special interests associated with advanced materials for the full range of Army applications. Work in this PE is related to and fully coordinated with efforts in PE 0602618 (Ballistics Technology), PE 0602601 (Combat Vehicle and Automotive Technology), PE 602782 (Command, Control, Communications Technology), PE 0602786 (Warfighter Technology), PE 0603001 (Warfighter Advanced Technology), PE 0603004 (Weapons and Munitions Advanced Technology), PE 0603005 (Combat Vehicle Advanced Technology), PE 0603008 (Command, Control, Communications Advanced Technology), and PE0708045 (Manufacturing Technology). The cited work is consistent with Strategic Planning Guidance, the Army Science and Technology Master Plan (ASTMP), the Army Modernization Plan, and the Defense Technology Area Plan (DTAP). Work in this project is performed by the Army Research Laboratory (ARL) is intended to transition materials technologies and support the Army materiel efforts at the Armaments Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, NJ; the Tank and Automotive Research, Development and Engineering Center (TARDEC), Warren, MI; the Aviation and Missile Research, Development and Engineering Center (AMRDEC), Huntsville, AL; the Natick Soldier Center, Natick, MA; the Edgewood Chemical and Biological Center, Edgewood, MD; and the Communications and Electronics Research Development and Engineering Center (CERDEC), Ft. Monmouth, NJ.

Note: In FY05, the ongoing effort in nanomaterials previously funded in Project H84 has been restructured into a separate project for heightened visibility and management (Project H7G – Nanomaterials Applied Research).

| B. Program Change Summary | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|
| Previous President's Budget (FY 2005) | 15385 | 14701 | 15464 |
| Current Budget (FY 2006/2007 PB) | 50788 | 17559 | 18236 |
| Total Adjustments | 35403 | 2858 | 2772 |
| Net of Program/Database Changes | | | |
| Congressional Program Reductions | -739 | | |
| Congressional Rescissions | | | |
| Congressional Increases | 37300 | | |
| Reprogrammings | | | |
| SBIR/STTR Transfer | -1158 | | |
| Adjustments to Budget Years | | 2858 | 2772 |

Change Summary Explanation:
FY06 - Increased funding ($2858K) to enhance Applied Research in Materials including Nanomaterials Technology to improve the survivability and lethality of Future Force systems and where feasible, exploit opportunities to enhance Current Force capabilities including individual soldier protection.
FY07 - Increased funding ($2772K) to enhance Applied Research in Materials including Nanomaterials Technology to improve the survivability and lethality of Future Force systems and where feasible, exploit opportunities to enhance Current Force capabilities including individual soldier protection.

Seventeen FY05 Congressional Adds totaling $37300 were added to this PE.

FY05 Congressional Adds with no R-2A:
Advanced Materials for Mine Detection and Blast Mitigation, Project H7B ($2397)
Advanced Materials Processing for Future Combat Systems, Project H7B ($6712)
Ballistic Shields Program, Project H7B ($959)
Composite Materials Technology for FCS, Project H7B ($1918)

Design and Manufacturing Process Technology for High Performance Polymer Nano-Composites, Project H7B ($1247)
Development of Manufacturing Science for Lightweight Ceramic Armor, Project H7B ($959)
Engineered Surfaces for Weapons Systems Life Extension, Project H7B ($2685)
Future Affordable Multi-Utility (FAMU) Materials, Project H7B ($959)
Future Affordable Multi-Utility (FAMU) Materials for the Army FCS, Project H7B ($1726)
Materials Joining for Army Weapons Systems, Project H7B ($2493)
MEMS Sensors for Rolling Elements Bearings, Project H7B ($1247)
Micro-Laminate Ceramic Armor, Project H7B ($2493)
Molecular Design of Polymer Nanocomposites ($1151)
On-Demand Micro Electronics Manufacturing and Qualification, Project H7B ($1919)
Precision Polishing of Large Optics, Project H7B ($3261)
Tactical Armor Manufacturing Technology, Project H7B ($2685)
Ultrasonic Consolidation Matrix for Metal Composites, Project H7B ($959)

FY05 Congressional Adds and no R-2A are not defined due to space limitations.

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R2a Exhibit)

**February 2005**

| BUDGET ACTIVITY | PE NUMBER AND TITLE | PROJECT |
|---|---|---|
| **2 - Applied Research** | **0602105A - MATERIALS TECHNOLOGY** | **H7G** |

| COST (In Thousands) | | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate |
|---|---|---|---|---|---|---|---|---|---|
| H7G | NANOMATERIALS APPLIED RESEARCH | 0 | 4555 | 5006 | 5193 | 5323 | 5469 | 5577 | 5688 |

**A. Mission Description and Budget Item Justification:** This project integrates government and industry scientific capabilities on research to advance innovative nanomaterials technologies and exploit breakthroughs in nanomaterials basic research toward improving Future Force Warrior survivability, lethality, and sustainability. This project funds a collaborative research effort in nanomaterials technology between the Army Research Laboratory (ARL), the Institute for Soldier Nanotechnologies (ISN) at the Massachusetts Institute of Technology and the ISN's industry partners. The research is focused on nanomaterials and includes the development of models to facilitate the exploration of concepts for improving individual soldier protection . Nanomaterial research holds promise in providing the capability to tailor the mechanical and thermal response of materials to enable desired performance improvements specific to the application of interest. The cited work is consistent with Strategic Planning Guidance, the Army Science and Technology Master Plan (ASTMP), the Army Modernization Plan, and the Defense Technology Area Plan (DTAP). Work in this project is performed by the Army Research Laboratory (ARL).

The work in this project was previously funded in PE 0602105A project H84. In FY2005, a separate project to heighten visibility of the efforts in this important area of material research and focus on improvements in individual soldier protection.

| Accomplishments/Planned Program | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| - Devise and validate improved physics-based materials property models and concepts for multifunctional lightweight and responsive hierarchical material technologies and exploit breakthroughs in nanomaterials and multifunctional fiber processing technologies (e.g., scale-up of processes and fabrication into woven materials) to enable revolutionary Future Force Warrior protection capabilities. Coordinated research program conducted internally, by ARL, externally by ISN industry partners, and through collaboration with ARL and ISN industry partners. In FY05, devise protective materials concepts that could be incorporated into multifunctional capabilities (e.g., ballistic, blast and fire/flame protection) with reduced weight within single integrated system. Exploit selected processing methodology to fabricate prototype nanomaterials-based, functionally integrated specimens for evaluation with improved survivability and lethality. In FY06, will investigate materials technologies and incorporate into flexible multi-material assemblies and determine performance of newly developed materials systems. In FY07, will mature multi-functional materials concepts to include addressing scalable processing and fabrication methods. | 0 | 4555 | 5006 | 5193 |
| Totals | 0 | 4555 | 5006 | 5193 |

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R2a Exhibit)

**February 2005**

| BUDGET ACTIVITY | PE NUMBER AND TITLE | PROJECT |
|---|---|---|
| **2 - Applied Research** | **0602105A - MATERIALS TECHNOLOGY** | **H84** |

| COST (In Thousands) | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate |
|---|---|---|---|---|---|---|---|---|
| H84 MATERIALS | 14623 | 10475 | 12553 | 13043 | 13918 | 14121 | 14291 | 14440 |

**A. Mission Description and Budget Item Justification:** The goal of this project is to provide the technical foundation for materials technology in metals, ceramics, polymers, and composites that are essential for lethal and survivable Future Combat Systems (FCS), Future Force Warrior (FFW) and other Future Force platforms. In order to meet the challenge of Army Transformation, new systems must be significantly lighter, more deployable, and more sustainable. Achieving such systems requires new materials and structures solutions that offer significant weight reduction with improved performance, durability and cost reduction for application to individual soldier support equipment, armor, armaments, aircraft, ground combat vehicles, and combat support equipment. This project will address these needs through: nanomaterials research across the spectrum of applications to improve performance, improved physics-based material, mechanics, and structural models; high strain rate material characterization techniques; non-destructive inspection/evaluation technologies; new high strength/temperature materials and coatings; and advanced fabrication/processing methodologies. Applied research efforts are focused in armor/armament materials, as well as lightweight structural materials and materials affording protection against chemical, biological, or directed energy threats. Overarching goals of the material research are to provide optimized lightweight armor structures, improved affordable processing methods, and the development of modeling and simulation tools to facilitate future design efforts in support of FCS and FFW. The work is conducted by the Army Research Laboratory (ARL), at its Aberdeen Proving Ground, MD and Hampton, VA locations, and provides required technologies for advanced development programs at the Armaments Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, NJ; the Tank and Automotive Research, Development and Engineering Center (TARDEC), Warren, MI; the Aviation and Missile Research, Development and Engineering Center (AMRDEC), Huntsville, AL; the Natick Soldier Center, Natick, MA; the Edgewood Chemical and Biological Center, Edgewood, MD; and the Communications and Electronics Research Development and Engineering Center (CERDEC), Ft. Monmouth, NJ. In FY04, this project funded the collaborative research effort in nanomaterials technology between the ARL and the Institute for Soldier Nanotechnologies (ISN) at the Massachusetts Institute for Technology, MA. This effort, associated only with nanomaterial research for the specific application of soldier protection, transitions to 0602105A H7G in FY05. The cited work is consistent with Strategic Planning Guidance, the Army Science and Technology Master Plan (ASTMP), the Army Modernization Plan, and the Defense Technology Area Plan (DTAP). Work in this project is performed by the Army Research Laboratory (ARL).

| **Accomplishments/Planned Program** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| - Optimize lightweight armor materials/structures, processing methodology, and modeling and simulation tools to enable formulation of lightweight frontal and structural armors that will revolutionize the survivability of FCS, Current and Future Force Platforms and Ground Tactical Vehicles. In FY04, provided and evaluated improved materials and processes to include multi-spectral and transparent ceramics that increase performance of armor systems; and established computational methodologies for design of blast and impact-resistant multifunctional (e.g., providing combined power, communications, propulsion, or sensory capabilitites) composite structures for enhancement of FCS systems. In FY05, validate enhanced structural armor, metallics, and ceramics to enable advanced armor technology formulation; and validate computational methodologies for design of blast and impact-resistant multifunctional composite structures critical to improving the survivability of Current and Future Force platforms. In FY06, the validated computational models will be used to design and fabricate multi-material assemblies to achieve optimized multi-spectral properties. In FY07, will evaluate these multi-functional assemblies against ballistic, mine blast and other emerging threats. | 4209 | 4201 | 4223 | 4631 |
| - Optimize lightweight armor materials and defeat mechanisms against emerging threats to enable affordable design of future multifunctional ballistic protective systems for the Future Warrior. Provide quantitative scientific basis for modeling and simulation that result in new lethal mechanisms/protection schemes for the individual warfighter. In FY04, optimized lightweight armor materials and defeat mechanisms against emerging threats and provided prototype armors to the Natick Soldier Center that incorporated advanced processing techniques enabling affordable design of future multifunctional ballistic protective systems for the Future Force Warrior. In FY05, devise new physics-based simulation capability to model the effects of ballistic, blast, or shock impact and stab incidence on the warfighter; investigate novel armor materials and processing techniques to devise concepts for soldier extremities protection. In FY06, will exercise initial simulation codes against known threats and current protection schemes and refine models as required; will incorporate lightweight armor materials and novel defeat mechanisms into concepts to improve Soldier extremity protection. In FY07, will validate simulation and design tools for individual warfighter protection and lethality applications and transition promising protection/lethality concepts to development community. | 1566 | 2251 | 2434 | 2467 |

| **Accomplishments/Planned Program (continued)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| - Design, validate, and optimize advanced materials (ceramic, composite, polymers, lightweight and high metals) and processing techniques for smaller but more lethal penetrators/warheads and affordable, lightweight high performance armaments for revolutionary Future Force lethality. In FY04, characterized failure mechanisms in emerging anti-armor materials and investigated effects of processing variables and constituents for improved design of penetrators/warheads; showed thermally robust sheathing techniques capable of inducing a multi-axial compressive stress to insure structural integrity of sheathed ceramics subjected to internal pressure loading to enable improved armaments for the Future Force. In FY05, transition improved ceramic gun barrel technology to ARDEC/AMRDEC, and produce sub scale penetrators from emerging amorphous metals and unique alloys. In FY06, will characterize full scale penetrators and provide alloy/penetrator manufacturing process diagrams for production and transition to industrial partners; will investigate behavior of metal matrix composites subjected to tensile load over the range of operational temperatures typical for cannons. In FY07, will mature processes and techniques for fabricating ultra-fine grain materials that result in penetrators with improved strength and stiffness; will identify and prove out a process for application of an erosion-resistant appliqué on a lightweight composite cylinder to enable future lightweight armaments. | 3705 | 3523 | 3449 | 3480 |
| - Design and optimize electro-ceramic materials and processing techniques for integration by CERDEC into advanced antennas that will enable affordable, reliable Command, Control, Communications (C3) information for FCS and Future Force platforms. In FY04, successfully integrated Barium Strontium Titanate (BST) with a thin layer on silicon substrates, using deposition and integration parameters that yielded optimum device material properties, that can be processed in silicon wafer foundaries, thereby significantly reducing the cost and improving the device yield. In FY05, transition materials technology to CERDEC for incorporation into devices. In FY06, will establish life testing methodologies to evaluate reliability of thin film-based structures. In FY07, will investigate novel materials concepts to increase the temperature stability of active thin film materials. | 500 | 500 | 500 | 500 |

| **Accomplishments/Planned Program (continued)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| - Devise and validate improved physics-based materials property models and concepts for multifunctional lightweight and responsive hierarchical material technologies and exploit breakthroughs in nanomaterials and multifunctional fiber processing technologies (e.g., scale-up of processes and fabrication into woven materials) to enable revolutionary Future Force Warrior protection capabilities. Coordinated research program is conducted internally, by ARL, externally by ISN Industry Partners, and through collaboration with ARL and ISN Industry Partners. In FY04, designed and devised scalable processing/synthesis methods and showed improved physics-based materials property models applicable for soldier protection concepts. In FY05, Project H7G has been initiated to provide a clear and focused effort for nanotechnology as it relates to individual soldier protection. | 4643 | 0 | 0 | 0 |
| - Mature and scale-up nanomaterials processes, fabrication, characterization, and performance measures to enable revolutionary concepts for Future Force lethality and survivability beyond those addressed for individual soldier protection in H7G. In FY06, will devise nanomaterial concepts to produce lightweight transparent structural materials systems; mature processing methods to produce nanometallic materials; validate nanomaterial enhancements to improve structural and impact properties of polymer composite materials; devise nanomaterial additives for use in military coatings system improvements; and mature unique experimental and numerical methods to characterize the mechanical response of nanomaterials. In FY07, will mature design capabilities for advanced nanomaterials and validate scalable processing methods; investigate effects of nanoengineering on the mechanical and physical properties of composite materials; quantify effects of nanomaterial modified coating systems on materials performance; modify and mature improved physics-based nanomaterials property models. | 0 | 0 | 1947 | 1965 |
| Totals | 14623 | 10475 | 12553 | 13043 |