

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2 Exhibit)

February 2002

BUDGET ACTIVITY  
**2 - Applied Research**

PE NUMBER AND TITLE  
**0602618A - BALLISTICS TECHNOLOGY**

COST (In Thousands)	FY 2001 Actual	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate
Total Program Element (PE) Cost	52245	60948	74094	65408	67445	61385	62905
H03 ROBOTICS TECHNOLOGY	13933	24016	19013	21971	22938	19307	19655
H75 ELECTRIC GUN TECHNOLOGY	9374	4973	8325	9100	10971	10647	11084
H80 BALLISTICS TECHNOLOGY	28938	31959	46756	34337	33536	31431	32166

**A. Mission Description and Budget Item Justification:** This program element (PE) provides ballistic technologies required for armaments and armor to support the Future Combat Systems (FCS) and the Objective Force and to allow US dominance in future conflicts across a full spectrum of threats in a global context. Project H75 focuses on pulsed power technologies for electric armaments which offer the potential to field leap-ahead capability in providing hypervelocity and hyperenergy launch well above the ability of the conventional cannon. It also includes work in hypervelocity penetrator effectiveness and electrothermal chemical (ETC) technology that will greatly increase anti-armor capabilities. Project H80 is focused on applied research in ballistics technology to enhance the lethality and survivability of future weapons. Focus areas included advanced solid propellants, launch and flight dynamics, weapons concepts for light forces, warheads and projectiles, armor and munition/target interactions. Project H03 is a restructure from Project H80 to conduct applied research for advanced autonomous mobility technology for future land combat systems of the Objective Force. Included in H03 is a total \$43.4M in funding transferred from OSD to the Army's Robotics Program from FY01 to FY05. Projects AH03 and AH80 will enable lethality and survivability technologies for the Future Combat Systems (FCS). The cited work is consistent with the Army Science and Technology Master Plan (ASTMP), the Army Modernization Plan and Project Reliance. The program element contains no duplication with any effort within the Military Departments. Work is performed by the Army Research Laboratory. This program supports the Objective Force transition path of the Transformation Campaign Plan (TCP).

**ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2 Exhibit)**

**February 2002**

BUDGET ACTIVITY  
**2 - Applied Research**

PE NUMBER AND TITLE  
**0602618A - BALLISTICS TECHNOLOGY**

<u><b>B. Program Change Summary</b></u>	FY 2001	FY 2002	FY 2003
Previous President's Budget (FY2002 PB)	53258	61502	56705
Appropriated Value	53750	61502	0
Adjustments to Appropriated Value	0	0	0
a. Congressional General Reductions	0	-554	0
b. SBIR / STTR	-1113	0	0
c. Omnibus or Other Above Threshold Reductions	0	0	0
d. Below Threshold Reprogramming	100	0	0
e. Rescissions	-492	0	0
Adjustments to Budget Years Since FY2002 PB	0	0	17389
Current Budget Submit (FY 2003 PB )	52245	60948	74094

Change Summary Explanation:

FY03 (+13276) - Project H80 (+10170) increased to investigate advanced componentry necessary to implement revolutionary armor technology for the Future Combat Systems; Project H75 (+3103) increased to fabricate and prove critical components for electromagnetic gun.

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2A Exhibit)

February 2002

BUDGET ACTIVITY <b>2 - Applied Research</b>	PE NUMBER AND TITLE <b>0602618A - BALLISTICS TECHNOLOGY</b>					PROJECT <b>H03</b>	
COST (In Thousands)	FY 2001 Actual	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate
H03      ROBOTICS TECHNOLOGY	13933	24016	19013	21971	22938	19307	19655

**A. Mission Description and Budget Item Justification:** This project advances autonomous mobility technology for the Future Combat Systems (FCS) and the Objective Force. It will investigate robotics technology critical to the development of future Army systems, including unmanned elements of the FCS and crew aids for future manned systems. It provides the basis for a tri-service research consortium joining researchers from DOD, other Government agencies, industry, and academia in a concerted, collaborative effort to advance key enabling technologies. Achieving these goals will provide future land combat forces with significant new operational capabilities permitting paradigm shifts in the conduct of ground warfare, providing significantly greater survivability and deployability. Technical efforts will be focused towards advancing perception for autonomous ground mobility, intelligent vehicle control and behaviors, and human supervision of unmanned ground systems. Research will be conducted at the Army Research Laboratory, other DOD laboratories and research centers, NIST, NASA and DOE research laboratories, as well as industry and academic institutions. The applied research conducted in this program will be transitioned to technology development, demonstration and materiel acquisition programs being conducted by the OSD Joint Robotics Program and each of the Services. Robotics Technology (Project H03) was previously funded in Project H80 prior to FY2001. The cited work is consistent with the Army Science and Technology Master Plan (ASTMP), the Army Modernization Plan, and Project Reliance. The program element contains no duplication with any effort within the Military Departments. Work is performed by the Army Research Laboratory. This program supports the Objective Force transition path of the Transformation Campaign Plan (TCP).

**FY 2001 Accomplishments:**

- 2000      - Established Collaborative Technology Alliance, an external research consortium, involving Industry, Academia and Historically Black Colleges and Universities and Minority Institutions (HBCU/MI's) to conduct applied research on the topics of perception, intelligent control and man/machine interfaces supporting development of the Future Combat Systems.
- 11933      - Designed and integrated multi-sensor perception technology, including stereo and LADAR, required to implement baseline follower operation by unmanned ground vehicles (UGVs).
  - Showed robotic follower operation at speeds of 20 MPH on-road and 10 MPH off-road.
  - Devised and integrated machine perception technologies and color classification based algorithms to enable rapid classification of a baseline set of terrain types required for high-speed autonomous mobility.
  - Devised intelligent control strategies and implemented a multi-level (spatial and temporal) World Model to enable UGVs to execute a basic set of military behaviors.

**ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2A Exhibit)****February 2002**BUDGET ACTIVITY  
**2 - Applied Research**PE NUMBER AND TITLE  
**0602618A - BALLISTICS TECHNOLOGY**PROJECT  
**H03****FY 2001 Accomplishments: (Continued)**

- Integrated perception and control technologies into a group of four UGV testbed platforms. Showed semi-autonomous cross-country mobility at speeds of up to 20 MPH (day), corresponding to 50% of the speed of a manned High Mobility Multipurpose Wheeled Vehicle (HMMWV), terrain dependent.

- Integrated new perception techniques (LADAR and Stereo Imaging) with advanced on-board intelligent vehicle control architecture to attain major increases in autonomous vehicle performance. Performance increases were evaluated on rugged, complex terrain at Ft. Knox, KY and on even more challenging terrain at Ft. Indiantown Gap, PA. Made all technical and logistical preparations necessary for Demo III, which comprises a set of technical and tactical evaluations to examine the maturity of autonomous mobility technologies (scheduled for 1Q FY02 at Ft. Indiantown Gap).

Total 13933

**FY 2002 Planned Program**

- 7928 - Execute industry/academic consortium for advanced perception, control/behavior and man-machine interface technology required for high-speed mobility (including robotic follower operations) and basic tactical behaviors common to multiple military missions.
- 8160 - Devise simulation based design tools for the development of tactical behaviors for UGVs.
  - Devise and integrate mid-range perception technology and control architecture required for development of tactical behaviors.
  - Integrate technology on testbed platforms and conduct engineering and troop experimentation to assess performance of perception and intelligent control algorithms.
- 7928 - Adapt and characterize sensors for autonomous navigation and mobility application in the ground combat environment with emphasis on affordability.
  - Expand test-bed infrastructure to enable accelerated autonomous mobility technology development through comprehensive field data collection and experiments.
  - Expand modeling and simulation infrastructure to enable accelerated autonomous mobility algorithm development and evolution.

Total 24016

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2A Exhibit)

February 2002

BUDGET ACTIVITY  
**2 - Applied Research**

PE NUMBER AND TITLE  
**0602618A - BALLISTICS TECHNOLOGY**

PROJECT  
**H03**

## FY 2003 Planned Program

- 8034 - Execute industry/academic consortium for advanced perception, control/behavior and man-machine interface technology to permit semi-autonomous cross-country mobility at speeds of up to 35 MPH during daylight and future implementation of complex tactical behaviors.
- 10979 - Integrate perception and control technology required for an intelligent follower vehicle capable of achieving 35 MPH on-road and 20 MPH off-road mobility (chassis limited) with a time delay between passage of the manned leader vehicle and unmanned follower of up to 12 hours.
  - Devise and implement baseline hard-coded tactical behaviors.
  - Integrate technology on testbed platforms, conduct engineering and troop experimentation for assessment of technology maturity, particularly with regard to inclusion in core FCS. Show tactical behaviors for "preceder" missions such as the autonomous utilization of terrain to mask movement and minimize vulnerability over multi-kilometer routes.

Total 19013

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2A Exhibit)

February 2002

BUDGET ACTIVITY  
**2 - Applied Research**

PE NUMBER AND TITLE  
**0602618A - BALLISTICS TECHNOLOGY**

PROJECT  
**H75**

COST (In Thousands)	FY 2001 Actual	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate
H75 ELECTRIC GUN TECHNOLOGY	9374	4973	8325	9100	10971	10647	11084

**A. Mission Description and Budget Item Justification:** This project funds applied research for the Army Electromagnetic (EM) armaments technology program. To achieve the objectives of the Army Vision, future armored combat vehicles, including the Future Combat Systems (FCS), will require more lethal, yet compact main armament systems capable of defeating protection levels greatly in excess of currently experienced values. The goal of this project is to evaluate the potential of EM Armaments to field a leap-ahead capability by providing adjustable velocities, including hypervelocity, greatly above the ability of the conventional cannon. EM armaments potentially can be fully integrated with electric propulsion and electromagnetic armor systems to provide the efficient, highly mobile, and deployable armored force required by the nation. This project focuses on addressing technical barriers associated with an EM armament, in particular with pulsed power for electromagnetic (EM) launches. This project funds a new contractual effort to devise and evaluate an efficient pulsed power technology for electromagnetic (EM) launch. The goal is to provide pulsed power technology (rotating machines) with energy density of ten Joules per gram (J/g) and to identify a clear potential for growth required for future combat systems, expected to be greater than fifteen J/g. Efforts in EM pulsed power systems are conducted by Lockheed Martin - Missile and Fire Control - Dallas, TX; CEM - University of Texas - Austin, TX; Kaman Aerospace Corp. - Boston, MA; IAP - Dayton, OH; Maxwell - San Diego, CA; GE - NY; and LMCS - NY. This project funds applied research for the Army Electrothermal Chemical (ETC) gun technology program with contractual efforts by SAIC - San Diego, CA; UDLP - Minneapolis, MN; and Thiokol - Ogden, UT, in close collaboration with the Armaments Research, Development, and Engineering Center, Picatinny NJ, applying ETC technology to potential armament systems for the Future Combat System (FCS) in both medium and large caliber with the FY02 goal of increasing muzzle energy by 25%. The cited work is consistent with the Army Science and Technology Master Plan (ASTMP), the Army Modernization Plan, and Project Reliance. The program element contains no duplication with any effort within the Military Departments. Work is performed by the Army Research Laboratory. This program supports the Objective Force transition path of the Transformation Campaign Plan (TCP).

**FY 2001 Accomplishments:**

- 4674 - Completed design of EM armament system including projectile, launcher, and pulsed power system.
- Conducted experiments showing material properties of pulsed power components (composite bandings and arbors, conductors, thermal management components, and semi-conductors) for the pulsed alternator machine.
- Devised initial switch array for multi-phase, multi-pole control of pulsed power machine and built converter prototype for field energy recovery.
- Devised model of integrated EM gun system and applied to prediction of anticipated machine performance.

**ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2A Exhibit)****February 2002****BUDGET ACTIVITY  
2 - Applied Research****PE NUMBER AND TITLE  
0602618A - BALLISTICS TECHNOLOGY****PROJECT  
H75****FY 2001 Accomplishments: (Continued)**

- 2700 - Designed and built prototype EM launchers at 60-mm equivalent scale to demonstrate robust, lightweight performance
- 2000 - Showed controlled step-up toward increased muzzle energy goal of 25% in medium caliber ETC cannon using tailored solid propellants.
  - Proved ETC injector technology compatibility with cased telescope cartridges.
  - In coordination with ARDEC verified 40% reduction in recoil forces using ETC and Fire-Out-of-Battery technology.

Total 9374

**FY 2002 Planned Program**

- 3982 - Generate advanced high power switches for converters for EM pulsed power system.
  - Design and evaluate controller for multi-phase, multi-pole operation of pulsed power machine.
  - Conduct experiments on full-scale medium caliber launcher and launch package designs demonstrating robust, field-worthy attributes.
  - Utilize EM Gun technology component models for conducting system level simulations
- 991 - Show an optimal increase in muzzle kinetic energy with ETC for an FCS Multi-Role Armament System.
  - Identify fieldable ETC tailored propellant.

Total 4973

**FY 2003 Planned Program**

- 8325 - Finalize design of EM gun system and procure long-lead items.
  - Fabricate and prove full scale critical components and evaluate at design limits.
  - Fire fieldworthy 60-mm launcher and integrated launch packages to full muzzle energy at 2300 meters/second.
  - Analyze combat utility of EM equipped platforms.

Total 8325

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2A Exhibit)

February 2002

BUDGET ACTIVITY  
**2 - Applied Research**

PE NUMBER AND TITLE  
**0602618A - BALLISTICS TECHNOLOGY**

PROJECT  
**H80**

COST (In Thousands)	FY 2001 Actual	FY 2002 Estimate	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate
H80 BALLISTICS TECHNOLOGY	28938	31959	46756	34337	33536	31431	32166

**A. Mission Description and Budget Item Justification:** The goal of this project is to provide key technologies required for armor and armaments that will enable U.S. dominance in future conflicts across a full spectrum of threats. The program supports the Army Vision by focusing on more lethal and more deployable weapons and on survivability technologies to lighten and protect Future Combat Systems (FCS) and the Objective Force. The barrier to this challenge is to insure combat overmatch and the survivability of the FCS in spite of its light weight (less than 20 tons). Specific technology thrusts include: lightweight armors and structures to defeat existing and emerging ballistic threats; Kinetic Energy (KE) Active Protection (KEAP) to defeat/degrade threats before they reach the combat platform; crew and component protection from ballistic shock, mine-blast, and fuel or ammunition fires; insensitive high energy propellants/munitions to increase lethality of compact weapon systems and to reduce propellant/munition vulnerability to attack; novel KE penetrator concepts to maintain/improve lethality while reducing the size/mass of the penetrator; novel multi-function warhead concepts to enable defeat of full-spectrum of targets (anti-armor, bunker, helicopter, troops); smart projectile technologies for launch, flight, and precision strike; physics-based techniques, methodologies, and models to analyze combat effectiveness of future technologies for improved ballistic lethality and survivability. Prior to FY01, this project also provided key technologies for a new class of vehicle control that will enable an unmanned land combat vehicle to intelligently follow a manned combat vehicle (technology is funded and executed in Project H03 beginning in FY01). This new capability will enable a manned crew in a lightly armored vehicle to simultaneously expand its survivability and area of influence, maneuvering and engaging enemy forces without disclosing its own location. The work is conducted at the Army Research Laboratory, Aberdeen Proving Ground, MD 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; and the Aviation and Missile Research, Development and Engineering Center (AMRDEC), Huntsville, AL. The cited work is consistent with the Army Science and Technology Master Plan (ASTMP), the Army Modernization Plan, and Project Reliance. The program element contains no duplication with any effort within the Military Departments. This program supports the Objective Force transition path of the Transformation Campaign Plan (TCP).

**FY 2001 Accomplishments:**

- 22112 - Designed and characterized innovative, lightweight armor technologies and survivability concepts at FY01 goal weight to enable survivable Future Combat Systems (FCS).
  - Evaluated multi-disciplinary design tools that couple structural analysis, aerodynamics, and guidance, navigation, and control (GN&C) technologies and applied to novel flight control designs for precision munitions, missiles, and rockets.

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2A Exhibit)

February 2002

BUDGET ACTIVITY  
**2 - Applied Research**

PE NUMBER AND TITLE  
**0602618A - BALLISTICS TECHNOLOGY**

PROJECT  
**H80**

## FY 2001 Accomplishments: (Continued)

- Implemented selected gun propellant formulations (sample sizes) in scaled ballistic studies to show improved performance and propellant integrity with reduced vulnerability for ARDEC Advanced Technology Demonstration Program.
- Evaluated and characterized muzzle flash sensor suites for threat cueing and radar tracking of KE penetrator in support of TARDEC-ARL-ARDEC Full Spectrum Active Protection Program; performed full-scale experiments and modeling optimization studies resulting in improved robustness of candidate KE counter-munition concepts.
- Devised physics-based models and conducted experimental evaluations of jacketed KE penetrator and unitary Warhead lethal mechanisms, which will improve FCS lethality while reducing size and mass.
- 409 - Proved out the feasibility of future large caliber ETC guns in joint US/GE firings. Evaluated 3 ETC igniter concepts and 2 ETC propellant technologies based on FY00 downselect.
- 6417 - Implemented experimentally derived penetration and behind-armor debris algorithms to predict the lethality of U.S. medium caliber munitions against foreign tanks and personnel carriers.
- Implemented empirically based combined blast and fragment algorithms to more accurately model the effects of high explosive incendiary projectiles on the survivability of the Objective Force, including ground combat systems and helicopters.

Total 28938

## FY 2002 Planned Program

- 25155 - Evaluate second-generation lightweight armor technologies and apply modeling and simulation tools for improved performance of FCS armors and survivability concepts.
- Apply multi-disciplinary design tools, coupled with weapons effectiveness analyses, and maturing guidance, navigation and control (GN&C) technologies (DARPA, COTS, etc) to evaluate concepts for FCS precision munitions, missiles, and rockets.
- Characterize performance of high energy/acceptable vulnerability propellant formulation (GEN II) and transition to Armament Research Development & Engineering Center for implementation in advanced multi-role armament for FCS.
- Down-select optimum KE counter-munition defeat and sensor suite configurations for transition to full-scale KEAP breadboard demonstration.
  
- Improve fidelity of predictive models and perform optimization studies of selected gun and missile KE/Warhead lethal mechanism concepts.

# ARMY RDT&E BUDGET ITEM JUSTIFICATION (R-2A Exhibit)

February 2002

BUDGET ACTIVITY  
**2 - Applied Research**

PE NUMBER AND TITLE  
**0602618A - BALLISTICS TECHNOLOGY**

PROJECT  
**H80**

## FY 2002 Planned Program (Continued)

- 6804 - Characterize the ballistic-induced deformation of select composite armors and structural materials to predict the penetration and blast survivability of the FCS.  
- Devise engineering-based predictions of crew acceleration and detonation/explosive reactions of stowed ammunition for Objective Force ground vehicles impacted by moderately overmatching ballistic munitions.

Total 31959

## FY 2003 Planned Program

- 27769 - Optimize lightweight armor technologies for transition to FCS vehicle designers.  
- Optimize multi-disciplinary design tools and fully characterize high-g GN&C components for application to future precision munitions, missiles, and rockets.  
- Evaluate and characterize insensitive high-energy propellant candidates (ETC-specific) required for improving the performance and reducing the vulnerability of future missile and gun systems.  
- Integrate selected KE counter-munition and sensor suite into breadboard KEAP system and commence testing to optimize system performance and improve compactness/hardening of KE penetrator defeat technologies.  
- Breadboard selected KE/Warhead lethal mechanism components and transition to FCS armament designers for integration into KE missile or multi-role ETC ammunition.
- 7285 - Implement first generation advanced armor penetration algorithms in survivability/lethality analysis codes for sophisticated multi-layering schemes for multi-hit protection of U.S. Army ground systems and the Objective Force.  
- Provide the survivability/lethality analysis code framework to dynamically model the interaction of an incoming conventional ballistic threat versus a ground combat vehicle equipped with an active protection system.
- 10902 - Investigate advanced componentry necessary to implement revolutionary armor technology onto a lightweight FCS armor platform.  
- Optimize logic and control system to minimize space and weight claims of FCS armor system.
- 800 - Funds Reprogrammed for ARL lab management support.

Total 46756