RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

COST *(In Millions)*	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	Cost to Complete	Total Cost
Total Program Element (PE) Cost	16.242	13.007	14.786	14.790	14.916	15.233	15.553	15.880	Continuing	Continuing
DoD/DOE Munitions/P225	16.242	13.007	14.786	14.790	14.916	15.233	15.553	15.880	Continuing	Continuing

(U) A. Mission Description and Budget Item Justification

(U) BRIEF DESCRIPTION OF ELEMENT:

(U) This R&D program is a cooperative, jointly funded effort between DoD and DOE to pursue new and innovative warhead, explosive, and fuze technologies in order to bring about major improvements in non-nuclear munitions. This program supports the development and exploration of new munitions concepts and technology preceding system engineering development. Through our funding arrangement with DOE, DoD resources are matched. More importantly, this relatively small DoD contribution effectively taps the annual billion-dollar DOE RDT&E investment by accessing the specialized skills, scientific equipment, facilities and computational tools not available in DoD.

(U) The effort exploits the extensive and highly developed technology base resident in the National Laboratories relevant to achieving the goal of developing capable, cost-effective conventional munitions, and leverages DoD investments with matching DOE investments. The current program supports 43 projects in warhead technology, energetic materials, advanced initiation and fuze development, munitions lifecycle technology and demilitarization, and computer simulation. A specific Service laboratory sponsors each of these active projects. The program is administered and reviewed by a Joint Technical Advisory Committee composed of members from the Army, Navy, Air Force, OSD, and DOE. Projects are peer-reviewed semi-annually by DoD Service Laboratory/Technical Center personnel in order to monitor technical excellence and insure that the technologies under development address priority DoD needs. The program is integrated with Service efforts through the Project Reliance Weapons Panel and participation in the Defense Technology Area Plan for Conventional Weapons. The program is reviewed under the Technology Area Review and Assessment process.

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(U) Project Number and Title: P225/DoD/DOE Munitions

(U) PROGRAM ACCOMPLISHMENTS AND PLANS:

(U) FY1998 Accomplishments:

(U) This development effort continues to provide improved component options for use in robust, low-cost, miniature electronic safing, arming and firing systems. The objective is to provide a set of characterized, qualified, generic components (and suppliers) and to demonstrate their use in prototype designs. The primary challenge is to significantly reduce system size and cost while increasing the operational capability and survivability and maintaining safety and reliability. A further challenge is to extend the technology to high velocity penetrating weapons and to artillery and mortar rounds. The functionality and reliability of a new semiconductor switch was demonstrated that is a factor of 5 lower in cost and a factor of 10 smaller than the vacuum switch used in current systems. The firing voltage for chip-slapper detonators was decreased 30% by using composite flyers and aluminum bridges. Lower detonator voltage allows the use of smaller, lower-cost energy storage devices and other components. The functionality of redesigned 1 kV ceramic capacitors was demonstrated for fire set application to replace custom mylar units. Capacitor costs decreased from $100 to $2-$10; size decreased by a factor of 10. These new components have been demonstrated in a working prototype electronic safing and arming device (ESAD) that is 1.25 cubic inches in size with parts cost of $120. This represents a factor of 5 reduction in size and a factor of 4 reduction in cost over current state-of-the-art technology. Multi-point detonators are the enabling technology for advanced aimable and multi-mode warheads. A 20-point design utilizing new lower energy and lower voltage Safe, Low-Input, Microslappers (SLIM) is being transferred to the Air Force contractor working on the multi-mode warhead for LOCAAS. Fast charge coupled devices (CCD) are being used to build a high-speed imaging (4000 frames/s) camera with a 512x512 pixel array for use in range-gated sensors and experiment diagnostics. Fabrication and testing of the imager at full pixel clock rate was completed. ($3.380 Million)

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

(U) DoD and DOE have very similar requirements for energetic materials. Both agencies desire high explosives with increased or tailored performance and decreased sensitivity. Recent accomplishments have benefited both agencies. LLM-105, a new energetic molecule that combines moderate energy with excellent insensitivity properties, was scaled up using a batch process to a 0.4-kg quantity. Instrumented shock loading tests showed a prototype formulation to be extremely insensitive, thereby increasing the likelihood of it becoming a practical material for munitions. A R&D 100 Award, given to the top 100 inventions in the US each year thought to have the greatest impact, was won for a new explosive compound that produces no smoke yet generates large quantities of gas. It is an excellent candidate material for low-signature rocket propellants. A hard target penetrator explosive, RX-35-EK, which combines nearly 50% increase in energetic performance with improved survivability, was transferred to Eglin AFB for testing. The CHEETAH 2.0 thermochemical code, used by over 250 DoD organization and contractors for prediction of the performance of high explosives (HE) as well as gun and rocket propellants, was released to users. This update tripled the database of HEs and enables CHEETAH to be used over a very comprehensive range of energetic materials problems. An initial code suite for use in multidimensional cookoff studies was completed and transitioned to the NAVY. This first-ever truly predictive capability for cookoff is composed of coupled thermal/mechanical/chemical codes for predicting when and where initiation occurs, along with shock physics tools for predicting the resulting violence of reaction. ($3.480 Million)

(U) Polymeric carbon monoxide, the first of a new and potentially very interesting class of metastable High Energy Density Materials (HEDM) was synthesized under very high pressure and temperature in the laboratory and recovered for characterization at ambient conditions. Energy content of this class of materials is predicted to exceed that of known high explosives by a factor of 2 to 4. Scale-up activities and performance evaluations continued on another new class of energetic materials, Metastable Intermolecular Composites (MIC), where 500 prototype MIC-based, green (lead-free) percussion primers for small-arms ammunition were produced and evaluated by the Army; all performance specs were met. Work on a carbon/hydrogen HEDM continued. The energy storage mechanism was established and preliminary experiments showing feasibility of production scale-up were completed. ($1.060 Million)

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

(U) Lagrangian and Eulerian hydrocodes, coupled code systems, arbitrary Lagrangian-Eulerian (ALE) codes, and supporting materials models and constitutive relations developed at the nuclear weapons laboratories, have been improved and adapted to DoD problems and transitioned to the DoD user community for use in warhead design and evaluation. This program provides prompt and direct access to the substantial investments in computational mechanics and materials modeling by the DOE and acts as the conduit for transition. Specific activities supporting the technology transition include distribution of computational tools to the DoD community, support of DOE codes on centralized DoD computing systems, training of the user community, and consulting as needed. The smooth particle hydrocode SPHINX, used for detailed endgame analyses of high-speed missile intercepts, was improved and adapted to parallel computer architectures. New materials and failure models required for this application were implemented. Material constitutive models for composites and explosives were developed using experimental data from a new Hopkinson bar made of magnesium, which allows dynamic strain rates of low-density materials to be determined. ($2.822 Million)

(U) A new concept for hard target weapons, the monolithic ballasted penetrator, has been developed that significantly increases velocity limits, penetration depth into concrete, and volume for energetic materials. The first prototype penetrator was fabricated demonstrating casting of ultra high strength alloy steel, net-shape processing and cost-effective manufacture. Preparations for testing are underway. Completed successful instrumented test of mid-scale conventional penetrator at high velocity (3500 fps) into concrete providing first detailed environmental data for components and payload at these conditions. These tests directly support the challenging problem of designing a fuze and payload that will survive high velocity impact into rock and concrete. A new level of shaped charge performance (classified), resulting from hydrocode design tools, was demonstrated. Two separate designs were developed; one of which originated from using the Global Local Optimizer (GLO) code coupled with the hydrocode CALE. GLO enhances the effectiveness of the designer approximately 10-fold. This was the first attempted use of GLO to accomplish a completely new warhead design. Both of the designs were successfully tested and achieved the predicted levels of performance. A new understanding of the influence of material properties on warhead liner performance provided the first correlation and explanation of the combined influence of material grain size and impurity concentration of liner ductility. ($3.250 Million)

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

(U) DoD and DOE efforts toward munitions lifecycle technologies including stockpile aging, surveillance, demilitarization and disposal are coordinated under the auspices of this program. Work was completed on molten salt and base-hydrolysis, two competing technologies for the destruction of explosives and other organic materials. Prototype units have been constructed and delivered for pilot plant use and evaluation. The molten salt destruction of energetic materials project was completed with transition of pilot plant reactors to the Bluegrass Ammunition Depot and to Air Force Research Laboratory at Eglin AFB. A portable base-hydrolysis unit and hydrothermal unit was designed, fabricated, tested and delivered to a DOE facility for evaluation. Initial tests were performed using a femtosecond laser, demonstrating the capability to cut through HE samples, both bare and inside of a case, without any evidence of chemical reaction in the HE. These test results served to initiate a major effort to exploit the technology for demilitarization and precision machining of HE. In collaboration with a DoD contractor a process was developed for cofiring rocket motor propellant washout waste streams contaminated with asbestos fibers. The presence of asbestos is a result of the washout process. Combustion conditions and control strategies were demonstrated that burns the residual propellant and transform the asbestos fibers into amorphous, harmless magnesium silicates. A prototype robotic workcell for disassembling 40-mm projectiles was developed and delivered to McAlester Army Ammunition Plant for testing and evaluation. Age-related degradation of materials within high value weapon systems was studied in order to understand and predict changes in munitions safety, performance and reliability during long term storage. Development of predictive models for materials and system aging was begun based on evaluation of stockpile materials and components. The focus is on solder interconnect reliability, corrosion of electronics with an emphasis on plastic encapsulated microcircuits, and the aging of propellants. ($2.250 Million)

(U) FY1999 Plans:

(U) Continue the improvement of electronic safing, arming and firing systems with a focus on reducing size and cost for application to artillery and mortar rounds and increasing shock survivability for application to high-velocity hard target penetrators. Continue to work with industry to establish commercial sources for qualified components and continue the transition of technology to developmental and fielded weapon systems. Complete the characterization of low-energy semiconductor bridge (SCB) slapper detonators and continue work on the producability, packaging and long-term reliability of chip and SCB slapper detonators. Complete development and testing of HNS-IV explosive formulations with binders for use in detonator pellets in high shock environments. Establish an alternate commercial source for the new semiconductor switch; the current supplier has decided to quit the defense business. Evaluate electron-bombarded CCD intensifier to improve sensitivity and resolution of high-speed imaging camera. Evaluate non-linear optical materials as imaging detector in near IR and initiate field tests. ($2.310 Million)

(U) Continue the development of HE with increased or tailored performance and decreased sensitivity. Initiate work on a more energetic hard target explosive with significantly improved survivability to meet the HE needs of the Navy and Air Force for a hypervelocity munition. Complete characterization

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

work on promising new energetic, insensitive molecule, LLM-105. Produce increased quantities and evaluate new high-nitrogen tetrazine-based explosives that promise decreased sensitivity while maintaining performance. Evaluate energetic elastomers based on dinitropropylacrylate for use as explosive binders having tailored glass transition temperature to reduce the embrittlement of explosives at low operational temperatures. Continue characterization of new, smokeless compounds for application in explosives and propellants. Continue work to predict the response of energetic materials in weapon systems subjected to thermal and mechanical insult. Fully characterize bulk and constituent properties of explosives PBX-9502 and PBXN-9, build constitutive models, and implement in 3D hydrocodes. Use these tools to predict HE response to hard target penetration environments. Experimentally assess and validate tools for predicting the violence of reaction in cookoff accidents. Continue the equation of state measurements on unreacted and off-Hugoniot states of HEs as a physical basis for developing the CHEETAH kinetics modeling capability. ($2.800 Million)

(U) Complete the characterization of polymeric carbon monoxide, the first metastable HEDM sample, in terms of its structure and energy content. Explore energy release mechanisms, continue the creation of new HEDM materials, and proceed with plans to scale up the high pressure and high temperature workcell. Scale up MIC fabrication capability to 1 kg/day operation and assist Army and Navy in evaluating alternatives for establishing fabrication capability at DoD facilities. Establish parameters for production of carbon/hydrogen in powder form and generate adequate powder to characterize its nature and properties. ($0.720 Million)

(U) Ongoing code and material model development will continue to focus on greater accuracy, improved physics, and extension to a broader class of real-world problems. Release new version of ALE3D in parallel architecture. Experimentally validate SPHINX simulations of high-speed missile intercept endgames. Implement improved and validated reactive and dynamic burn models into hydrocodes. Continue the development, implementation, and validation of material constitutive and failure models for incorporation into simulation tools. ($2.317 Million)

(U) Build four additional monolithic ballasted penetrator prototypes and test at mid-scale. Work supports Navy development of penetrating warhead for Standard Missile. Establish velocity limits and transition behavior for oblique and yawed impacts into limestone and weathered rock. Support the development of advanced reactive warhead concepts by evaluating how thin-film composition and structure affect the performance, deformation and failure of brittle films on ductile metal substrates. Continue the application of the optimizer code GLO to complex warhead design problems, as a powerful extension of design efficiency and capability. Use GLO to design warheads for increased penetration capability against concrete structures, for the integration of LX-19 into a tantalum explosively formed projectile (EFP) warhead, and for continuation of the high speed jet design. Continue the study of impurity effects on

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

the dynamic behavior of warhead liner materials. Continue the exploration and demonstration of the highest speed shaped charge jets attainable. Continue the dynamic study and analysis of liner formation and behavior, using infrared thermometry and fluorescence techniques, as well as high-speed, high-resolution optical techniques. Perform EFP tests to evaluate powder metallurgy tantalum vs. wrought material and determine the effects of specific textures and powder processes on warhead formation and performance. ($2.870 Million)

(U) Establish a testbed facility for the evaluation and exploitation of femtosecond laser cutting and machining of HE for use in munitions manufacturing and demilitarization processes. Initiate a parallel modeling effort to fully understand the femtosecond time-scale kinetics of the interaction of a laser pulse with energetic material. Improve vision and force control algorithms for the robotic workcell to increase operation rate of the disassembly of 40-mm Navy projectiles. Begin design and fabrication of tools and fixtures for automated disassembly of Improved Conventional Munitions (ICM) and safing of individual submunitions. In the study of materials aging characterize age-related physiochemical changes taking place in propellants to identify the cause of observed bulk property changes in composite rocket motors. The objective is to develop a constitutive propellant failure model to improve service-life predictive codes. ($1.990 Million)

(U) FY2000 Plans:

(U) Continue the development and demonstration of improved component options for use in robust, low-cost, miniature safing, arming and firing systems. Complete the characterization of detonators, capacitors, switches, etc. in shock environments for application to hard target munitions. Continue work on prototype ESAD sized for artillery and mortar rounds. Initiate work on an ESAD for hard target penetrators. The goal is to complete the design, fabrication and testing of a working prototype in FY2003. Complete high-speed imaging camera with electron-bombarded CCD and high-resolution frame grabber technology. ($2.430 Million)

(U) Continue the development of a low-sensitivity HE for application to hypervelocity hard target penetrators. The goal is to provide the Air Force and Navy with a high performance explosive formulation that will survive the impact of a hypervelocity penetrator into concrete. Complete characterization of new tetrazine-based explosives and select most promising candidate material for explosive and propellant formulations. Initiate formulation studies to optimize their performance in munitions systems. Evaluate the potential of sol-gel energetic materials for possible applications in high energy and high power explosives, precision detonator materials and detonation wave shapers, and pyrotechnics. Transition TATB-based technology developed for the nuclear weapons community to the DoD to meet IHE material requirements in a cost-effective manner. Continue pursuit and evaluation of highly energetic molecules with improved thermal stability. Continue development of equation of state for unreacted, partially reacted and fully reacted HEs, including non-ideal HEs,

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

through modeling and carefully diagnosed experiments. Information generated will be input into CHEETAH and transitioned throughout the DoD community. ($3.570 Million)

(U) Continue ongoing pursuit of new HEDM candidate materials having energy capacities 2-4 times that of HMX. Scale up production capabilities to provide gram-size material samples for characterization and study of energy release mechanisms. Transition fabrication technology for MIC materials to Army and Navy and complete economic assessments for establishing DoD production facilities. Complete study of carbon/hydrogen HEDM in terms of sensitivity, energy release potential, shelf-life stability and suitability for exploitation. ($1.010 Million)

(U) Continue development of Eulerian, Lagrangian, coupled and ALE codes relevant to the design and evaluation of munitions. Continue to incorporate improved materials models emerging from the DOE Advanced Strategic Computing Initiative to provide high resolution, accurate predictions of materials behavior and failure during warhead formation and warhead/target interactions. Support the transition of these tools to the DoD community. ($2.536 Million)

(U) Complete testing of ballasted penetrator concept for use against hard target. Develop and improve constitutive modeling of rock and soil and continue extensive benchmarking of codes and design tools against mid-scale and lab-scale tests. Provide fuze and payload developers with accurate predictions and measurements of penetration environments to support survivability testing. Produce and demonstrate prototype explosive projectile warheads using liners processed according to specifications developed from ongoing impurity and microstructural studies. Pursue hybrid EFP/jet and tandem concepts of defeat of specified hard targets. Evaluate utility of GLO-designed warhead concept for defeat of concrete targets. Transition high-speed jet designs to DoD to meet performance requirements well beyond the current state-of-the-art. ($3.340 Million)

(U) Begin tests in the femtosecond laser facility of cutting potential against large-scale HE samples and live munitions. Continue study of HE/ultra-short-pulse laser beam interactions through integration of modeling and well-diagnosed experiments. Delimit regions of utility for demilitarization and machining operations. Transition the process for synthesis of TATB, a high value explosive, by the direct conversion of waste Explosive D available from demilitarization operations. Demonstrate progress toward remote disassembly of 155-mm ICM artillery shells by remotely exposing submunition layers for handling and safing. The program goal is to implement integrated vision capabilities with force control and compliant tooling to demonstrate completely automated disassembly of ICMs with safing of individual submunitions by FY2002. Complete the predictive model for solder interconnect reliability based on mechanistic models of thermomechanical fatigue and fatigue crack propagation. Validate model using laboratory test samples and fielded test hardware. Continue the development of other materials and system aging models. ($1.900 Million)

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

(U) FY2001 Plans:

(U) Continue the development of advanced electronic safing, arming, and firing systems with a focus on small size, low cost and improved survivability. Demonstrate a working prototype of a generic ESAD sized for artillery and mortar rounds (less than 0.75 cubic inches) and with a further factor of two reduction in cost ($50 in parts). Continue work on the prototype hard target ESAD toward the planned demonstration in FY2003. ($2.430 Million)

(U) Transition HE and propellant formulations based on new tetrazine explosives to Services for safety qualification and application to munitions systems. Exercise the new hazards codes to evaluate the risk to munitions systems from a broad range of accident scenarios. Develop materials models that can predict new explosives molecules and their properties. Formulate explosives and propellants with enhanced properties such as lower sensitivity and smoke-free burning. ($3.600 Million)

(U) Complete characterization of metastable polymeric carbon monoxide and continue synthesis effort of other extended solid HEDM. Study the nature of phase transitions in solid nitrogen; pursue high hydrogen content material (BH3). Evaluate large volume press to scale up production. ($0.590 Million)

(U) Continue to develop, extend and apply the hydrocodes and associated materials models for warhead design and evaluation. Continue to support the transition of these tools, the training and consulting for the DoD user community. ($3.170 Million)

(U) Continue study of advanced hard target penetrator concepts and adapt designs to state-of-the-art materials and manufacturing methods. Continue development and validation of computational design tools and material models to extend penetrating weapon reliability and capability. Produce power metallurgy molybdenum and tungsten liners for enhanced warhead applications. Apply advanced modeling and simulation based design techniques to new warhead materials with energetic properties which couple to targets in order to increase efficiency and lethality. ($3.180 Million)

(U) Complete testing of the femtosecond laser cutting on live munitions and transition the technology to Services and DoD contractors for application to munitions manufacturing and demilitarization operations. Conduct full-scale demonstration of the direct chemical oxidation process for destruction of organic waste. This technique addresses the need for low-cost processing of empty shell cases to certify removal of trace quantities of explosives or toxic materials. Demonstrate integrated disassembly hardware and software algorithms in the robotic workcell for automated, remote disassembly of ADAM mine projectiles. Complete the predictive model for the reliability of plastic encapsulated microcircuits in dormant storage. This is important because commercial

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

specifications and test protocols do not accurately represent storage times and conditions for DoD munitions. Continue the development of other materials and system aging models. ($1.820 Million)

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3	R-1 ITEM NOMENCLATURE JOINT DoD/DOE MUNITIONS PE 0603225D8Z

(U) B. Program Change Summary	FY1998	FY1999	FY2000	FY2001	Total Cost
Previous President's Budget	16.141	16.354	15.290	15.306	Continuing
Appropriated Value	17.700				Continuing
Adjustments to Appropriated Value					
a. Congressionally Directed undistributed reduction	(0.733)	(.440)			
b. Rescission/Below-threshold Reprogramming, Inflation Adjustment	(0.058)				
c. Other		(2.907)	(.504)	(.516)	Continuing
Current President's Budget	16.242	13.007	14.786	14.790	Continuing

Change Summary Explanation:

(U) **Funding:** Funding changes in 1999, 2000, and 2001 are due to congressionally directed undistributed reductions and below threshold program adjustments.

(U) **Schedule:** Not Applicable

(U) **Technical:** Not Applicable

(U) **C. Other Program Funding Summary Cost** Not Applicable

(U) **D Acquisition Strategy :** Not Applicable

(U) **E. Schedule Profile** Not Applicable