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| RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit) | | | | | | | | DATE February 2000 | |
|--|---------|---------|---------|---------|---------|---------|---|------------------------------|------------|
| APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 3 | | | | | | | R-1 ITEM NOMENCLATURE Joint DoD/DOE Munitions PE 0603225D8Z | | |
| <i>COST(In Millions)</i> | FY 1999 | FY 2000 | FY 2001 | FY 2002 | FY 2003 | FY 2004 | FY 2005 | Cost to Complete | Total Cost |
| Total Program Element (PE) Cost | 12.553 | 14.315 | 16.670 | 16.785 | 17.083 | 17.382 | 17.687 | Continuing | Continuing |
| DoD/DOE Munitiond/P225 | 12.553 | 14.315 | 16.670 | 16.785 | 17.083 | 17.382 | 17.687 | 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 Munitiiond**

(U) **PROGRAM ACCOMPLISHMENTS AND PLANS**

(U) **FY1999 Accomplishments:**

(U) This development effort continues to provide improved component options for use in 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. A primary challenge is to extend the technology to high-velocity penetrating weapons and to artillery and mortar rounds. This requires significantly reducing system size and cost while increasing the operational capability and survivability and maintaining safety and reliability. Component advances in transformers, low-energy chip slapper detonators, capacitors and switches were achieved this year. These were demonstrated in a working prototype electronic safing and arming device (ESAD) that represents a factor of 7 reduction in size and a factor of 5 reduction in cost over currently fielded technology. New commercial vendors were successfully developed to replace component sources that have withdrawn from the defense business. A focus this year was on shock hardening to support Service initiatives in high-velocity penetrators. Critical ESAD components were shock tested to penetrating weapon environments of 35,000-G with encouraging results. Switches, capacitors and detonators as a group survived quite well. A penetrator survivable chip slapper detonator was developed using a new surface mounting technology. The assembled device, including slapper, cable and explosive column, was successfully fired after exposure to 35,000-G shocks. Tests were also performed on powered components. A switch/capacitor combination was fired under shock. Various formulations for detonator explosive pellets were developed and evaluated, and promising shock survivable candidates were identified. Multi-point detonators are the enabling technology for advanced aimable and target-adaptable warheads. Multi-point detonator arrays using 2, 4, and 40 low-energy chip slappers were successfully produced and fired. However, sensitivities of the detonator arrays to manufacturing variations in the detonators were identified. An effort to understand and accommodate the observed current oscillations and to provide more robust designs was initiated. (\$ 2.31 Million)

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(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. Characterization work was begun on LLM-105, a dense, thermally stable, insensitive high explosive with 81% of the energy of HMX. A more powerful explosive first synthesized by the Russians, diaminodinitroethylene (DADE), was also synthesized in sufficient quantities to obtain preliminary performance information. DADE appears to have performance similar to RDX with reduced sensitivity and appears to be an attractive candidate for use in advanced gun propellants. A joint evaluation/development program is underway with the Navy for both of these new materials. Two additional promising energetic materials have been identified: DAAF, an insensitive material with performance similar to Composition B, and ANTZDO, which is predicted to be more energetic than HMX but much less sensitive to impact. A bench-scale effort was initiated to produce sufficient DAAG material for further evaluation. Work continued on developing an optimum synthesis route for ANTZDO. The creation of the thermochemical code CHEETAH represents a major accomplishment of the program. This code predicts the performance of energetic materials, specifically, high explosives, propellants and pyrotechnics, and reduces the number of tests necessary to develop a new material. General release of Cheetah 2.0 occurred to over 300 DoD, DOE and DoD contractor users. This version includes new chemical kinetics capability that allows for modeling of time-dependent phenomena, such as partial combustion and detonations in composite explosives. A suite of codes is under development for use in predicting the response of energetic materials in weapon systems subjected to thermal and mechanical insult. A first-ever truly predictive capability for cookoff has been developed 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. An experimental effort was initiated utilizing micro-impulse radar, a new diagnostic technique that measures the rate of disassembly of a test fixture, to determine the violence of cookoff response. These data will be used to evaluate and validate the simulation tools. The response of energetic materials to low strain rate deformations, where the mechanical properties of the materials control the energetic response, is also under investigation. A unique split-Hopkinson pressure bar facility was completed that allows for the measurement of the dynamic stress-strain response of soft materials such as polymers and explosives, and also permits sample temperature control from -55 to +55° C. Measurements were completed on a variety of energetic materials and binders providing input for constitutive model development. The facility design was transitioned to the Navy at Indian Head where the Navy plans to replicate it. (\$ 2.8 Million)

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(U)High Energy Density Materials (HEDM) are under development that would significantly increase the effectiveness of the next generation of compact munitions. Recent calculations suggest that solid compounds derived from first and second row elements can be stabilized in configurations that would exhibit significant energy content. This year proof-of-existence and recovery to atmospheric pressure was demonstrated for a family of novel high-nitrogen molecular materials generated using high-pressure techniques. A new material synthesized at the highest pressures appears to be composed of only single bonded nitrogen, while the material created at lower pressures appears to have a mixture of single and double bonded nitrogen. Both of these materials are recoverable to ambient pressure and appear quite stable. Calculations of higher order molecules of nitrogen indicate that these materials should be very energetic, having energies several times that of any known high explosive. Another new class of energetic materials, Metastable Intermolecular Composites (MIC), uses thermite chemistry and unique processing technology which provides uniform nano-scale metal particles to make lead-free energetic materials. These materials are appropriate for use in non-toxic percussion primers for small caliber ammunition and aircraft evacuation mechanisms (CAD/PAD systems) and as reactive warhead fills and performance-enhancing additives for solid rocket propellants. MIC fabrication was scaled up to tens of grams per day in the laboratory with additional extensions and enhancements identified that are expected to support the desired production capability of 1 kg/day. Performance evaluations on the materials continued and tests by both the Army and Navy demonstrated that MIC-based materials meet the current operational requirements for both ammunition primers and for CAD/PAD applications at both high and low temperatures. Transition activities are now supported under the Green Bullet Program sponsored by the Strategic Environmental Research and Development Program (SERDP).

(\$ 0.52 Million)

(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.

(\$ 2.117 Million)

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(U)A major thrust of this program is hard target defeat. A new concept for hard target weapons, the monolithic ballasted penetrator, has been developed that significantly increases velocity limits, penetration capability into concrete, and volume for energetic materials. Manufacturing and casting development studies were completed, and two sound prototype penetrators have been produced in ultra-high-strength AeroMet 100 steel. Gun testing at velocities between 3000 and 3500 fps is scheduled for next year. Small-scale experiments to establish scale effects, velocity limits and transition behavior for oblique and yawed impacts into rock targets were initiated. Tests at high velocity against concrete targets reveal angle-of-attack sensitivities that will challenge system designs and will be the focus of further analyses and experimentation. To address the problem of designing an explosive payload that will survive high velocity impact into rock and concrete, a mid-scale projectile loaded with an explosive formulation of TATB that is thermally stable and extremely insensitive, was jointly tested with the Navy against a concrete structure at 3000 fps. Both the penetrator and explosive survived the impact. In anti-armor tasks the Global Local Optimizer (GLO) code, a non-linear optimization tool used to drive hydrodynamic design codes, was used by warhead designers to optimize and fine-tune the performance of warheads. GLO represents a new and powerful tool for the design of complex multi-parameter warhead systems. It was used to design a munition to produce a particular size and shape of hole into concrete and for generating high-speed jets in a classified project. GLO is estimated to enhance the effectiveness of the designer approximately 10-fold. Relating warhead performance to material properties requires a detailed knowledge of material properties under dynamic conditions and is considered a fundamental issue in computationally based design of future weapon systems. Significant progress has been made in showing for the first time how impurity levels and grain size combine to affect the material behavior in shaped charge liners.

(\$ 2.816 Million)

(U)DoD and DOE efforts toward munitions lifecycle technologies including stockpile aging, surveillance, demilitarization and disposal are coordinated under the auspices of this program. As the preferred method for demilitarization and disposal in DoD turns from open-burn and open-detonation to resource recycle and recovery, alternative technologies are required to turn waste materials into useful products. A successful demonstration was completed that utilized waste Explosive D available from demilitarization operations to form picramide, the starting material for synthesis of the insensitive explosive TATB, a high value product for both DoD and DOE. Scale-up efforts have been initiated and interested industrial partners have been identified for a pilot-plant demonstration. The potential for cutting explosives, both bare and encased in steel, has been demonstrated using a femtosecond laser. Unlike conventional cutting lasers that melt and vaporize material, the femtosecond laser ablates material with no evidence of heating. It offers unique capabilities for use in munitions demilitarization and manufacture. A laser testbed facility was established and cutting demonstrations completed on small components. To provide automated, remote capability for munitions demilitarization activities a robotic workcell for disassembling 155-mm projectiles was designed, prototyped, fabricated and is being assembled. When completed next year, it will provide the capability to completely disassemble M-483 rounds containing 88 bomblets. 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. The current focus is on solder interconnect reliability, corrosion of electronics with an emphasis on plastic encapsulated microcircuits, and the aging of propellants. Predictive models for materials and system aging are under development to support stockpile management strategies and improve service-life estimates.

(\$ 1.99 Million)

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(U) **FY2000 Plans:**

(U)Improvement of electronic safing, arming and firing systems will continue with a focus on shock survivability for hard target penetrators, multi-point detonator arrays for aimable and target-adaptable warheads, and development of a micro firing system. Shock testing of ESAD components will be expanded to encompass simultaneous axial and lateral shock environments as defined from instrumented high velocity penetration tests. The initial evaluation of shock survivability will be completed on all of the critical ESAD components. Detonator testing across the range of required environmental conditions, including cold, temperature cycling and humidity, will be performed to evaluate long-term reliability of the low-energy chip slapper assemblies. An effort will be initiated to validate electrical models of multi-point detonator arrays and to understand the electrical current oscillations observed during array firings. The objective of the work is to develop more robust multi-point system designs and to reduce the sensitivities in detonator performance to manufacturing and design variations. Recent advances in microelectronics, micro-electromechanical systems, micro-lasers and optical initiation offer opportunities for increased operational capability in electronic firing systems along with a further order of magnitude decrease in size. Initial exploration of a next generation system will begin; feasibility will be established by demonstrating new components, new architectures and enhanced integration. To preserve and transition the advanced electronic initiation technology base developed under this program, a computerized knowledge base will be established on design, manufacture, test and surveillance. This classified tool will ensure experience retention in archives and support government laboratories and contractors.

(\$ 2.35 Million)

(U)The development and characterization of new insensitive and new high-energy, high-power materials will continue with synthesis based on theoretical molecular design. The scale-up of newly synthesized materials, LLM-105, DADE, DAAF, and ANTZDO, will be completed and the predicted performance and material sensitivity properties will be confirmed. The investigation of sol-gel energetic materials will continue with a focus on their use in precision detonators and low-density gas generators. Formulations of a new family of smokeless energetics for possible exploitation in propellant applications will be explored. Release of CHEETAH 2.1 is planned which will contain an additional equation of state library with species calculated from first principles. The code is transitioning from an interpolative tool, calibrated to known explosives, to fully predictive. CHEETAH development will continue on equation of state for unreacted, partially reacted and fully reacted energetic materials, including non-ideal formulations, through modeling and carefully diagnosed experiments. Information will be input into subsequent CHEETAH updates and transitioned throughout the DoD community. Efforts to develop simulation tools for predicting munition system response to operational threat and accident environments will continue. A collaborative effort will be initiated with the Navy to experimentally assess and validate the just completed first-generation codes for predicting violence of reaction in cookoff accidents. Damage evolution and fracture behavior in energetic materials will be characterized using the new split-Hopkinson bar facility and scanning electron microscopy to support the development of energetic material constitutive models for use in the analyses of low strain rate mechanical deformation events.

(\$ 3.47 Million)

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(U)The creation of new High Energy Density Materials (HEDM) will continue. Characterization of polymeric carbon monoxide and the newly synthesized nitrogen molecules will be completed in terms of their structure and energy content. Energy release mechanisms will be explored and planning for scale-up of the high-pressure and high-temperature workcell will proceed. A viable process to produce 1 kg/day quantities of MIC materials will be established to demonstrate the feasibility of medium and large-scale applications. Transition of the technology to munitions programs will be supported. A new class of materials that consists of a composite of MIC material bonded to organic molecules will be explored.

(\$ 0.98 Million)

(U)The development of Eulerian, Lagrangian, coupled and ALE codes relevant to the design and evaluation of munitions will continue. Distribution of the newest DOE codes, a parallel version of ALE3D and the ALEGRA shock physics code, to DoD sites will be completed. Efforts will continue in the development, implementation and validation of material constitutive and failure models supporting the simulation of warhead formation and warhead/target interactions. The program also provides a conduit to the improved materials models emerging from the DOE Advanced Strategic Computing Initiative providing high resolution, accurate predictions of materials behavior and failure relevant to the analyses of weapon systems. The transition and support of these tools and models along with user training will be provided as needed.

(\$ 2.435 Million)

(U)Half-scale prototypes of the monolithic ballasted penetrator will be tested at 3000-3500 fps into concrete targets to evaluate penetrator behavior and performance. Small and mid-scale experimental and computational studies will be extended with an emphasis on oblique impact and rock targets. Constitutive models of rock and soil will be evaluated and improved. The focus of these studies is on establishing system limits for high-velocity penetrators and on resolving differences in codes and models. Collaborative studies will be performed on an Air Force identified low-alloy steel that holds promise as a low-cost replacement for current ultra-high-strength steels being postulated for future high-velocity penetrators. The physical metallurgy will be evaluated to optimize chemical and processing variables. Payload survivability during high velocity impacts will be studied via microscopic analysis of the LX-17 explosive that was recovered from the joint test with Navy against a concrete target. Damage to the explosive, including gross material motion along with fracture, failure, and changes to the microstructure, will be evaluated and characterized. The use of multiple shaped charge jet impacts will be evaluated as a means for degrading concrete targets and increasing hard target penetrator performance. Application of the optimizer code GLO to complex warhead design problems, as a powerful extension of design efficiency and capability, will continue. GLO will be used to evaluate warhead designs for increased penetration capability against concrete structures and to continue the development of high-speed jet designs in support of a classified Army program. Exploration and demonstration of the highest speed shaped charge jets attainable will be pursued. The study of dynamic material properties will continue. Work will focus on understanding the role of processing on the dynamic behavior of shocked warhead liner materials, specifically addressing the importance of impurities and microstructure on liner performance. Warhead liners processed according to specifications developed from these studies will be produced and demonstrated. Liner formation and behavior will be studied using infrared thermometry and fluorescence techniques, as well as high-speed, high-resolution optical techniques. Experimental techniques to measure post-shock temperature of material samples will be explored.

(\$ 3.24 Million)

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(U)The process for the direct conversion of waste Explosive D into TATB will be scaled-up from 1 kg to 10 kg in support of a planned FY2001 Navy manufacturing technology program to commercialize the process. Exploitation of femtosecond laser cutting and machining of explosives for both munitions demilitarization and manufacturing will continue. Testing in the new laser facility will begin to investigate optimum cutting rates, material limits, safety limits, and geometrical and size limits for explosives. A testbed capability for large (10-kg) explosive components will be established. A parallel modeling effort will study femtosecond time-scale kinetics of the interaction of a laser pulse with energetic material. Remote disassembly of 155-mm M-483 artillery shells to expose the submunition layers for handling and safing will be demonstrated. The program goal is to implement integrated vision capabilities with force control and compliant tooling to demonstrate completely automated disassembly of a cluster munition with safing of the individual submunitions by FY2002. Techniques will be explored for standoff monitoring of emissions from open-burn and open-detonation events. Development of materials and system aging models will continue. A predictive model for solder interconnect reliability based on mechanistic models of thermomechanical fatigue and fatigue crack propagation will be completed and validated using laboratory test samples and fielded test hardware. (\$ 1.84 Million)

(U) **FY2001 Plans:**

(U)Continue the development and demonstration of improved components and architectures for robust, low-cost, miniature safing, arming and firing systems. Continue to work with industry to establish commercial sources for qualified components and the transition of technology to developmental and fielded weapon systems. Complete the characterization of detonators, capacitors, switches, etc. in shock environments for application to hard target munitions toward the program goal of demonstrating a prototype ESAD in a high-velocity penetrator in FY2003. Continue the development of micro-firesets: develop and evaluate required components, improve integration, and demonstrate manufacturing technology. The program goal is a factor of 10 reduction in fireset size over the current low-energy designs. Resolve design issues with multi-point detonator arrays utilizing low-energy chip slappers and transition technology to DoD contractors. Continue support and development of knowledge base tool for preservation of advanced initiation technology. (\$ 3.54 Million)

(U)Continue efforts to synthesize, characterize and scale-up new energetic materials with increased or tailored performance and decreased sensitivity. Formulate and test smokeless propellants and determine performance/signature properties and scale up fabrication as needed for testing. Study experimentally the grain-scale dynamics of high explosives by observing the breakout of a detonation across the polished face of an HMX-based explosive. Explore the relationship between detonation front roughness and microstructure. Implement improved kinetics models into CHEETAH. Generalize the CHEETAH solvers to handle acid-base chemistry to improve results for explosives and propellants that contain ammonium chlorate. Exercise safety simulation tools against test data to validate codes and expand their ability to predict weapon system performance and response in accident situations. The joint experimental program with Navy will be expanded from simple to complex geometry tests. Testing and analyses of a full weapon system is scheduled for FY2002. (\$ 3.57 Million)

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(U)Complete characterization of metastable polymeric molecules and continue synthesis effort of extended solid high energy density materials. Study the nature of phase transitions in solid nitrogen; pursue high hydrogen content material (BH3). Evaluate large volume press to scale up production. Complete the transition of MIC-based materials to military applications.

(\$ 0.75 Million)

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

(\$ 3.3 Million)

(U)Continue the study of advanced hard target penetrator concepts and adapt designs to state-of-the-art materials and manufacturing methods. Complete small and mid-scale experimental and computational studies focused on scale effects, velocity limits and transition behaviors for oblique and yawed impacts into rock targets. Investigate weldability and melt processes to optimize properties and castability of the new Air Force low-cost penetrator steel. Evaluate and test the survivability of enhanced explosive payloads over the demonstrated LX-17 baseline. Continue the science-based technology projects relating warhead performance to material properties under dynamic conditions as a prelude to improved computational modeling and the transition of improved warhead designs to developmental and fielded weapon systems. Produce powder metallurgy molybdenum and tungsten liners for enhanced anti-armor warhead applications and conduct `soft-catch` tests using both prototype powder metallurgy and wrought material to permit model validation in complex, high-strain/high-strain-rate experiments.

(\$ 3.6 Million)

(U)Complete the evaluation of femtosecond laser cutting on live munitions and begin to identify specific applications of the technology for munitions manufacturing and demilitarization operations. Adapt the robotic workcell to the disassembly of Adam mine rounds. Design and simulate the disassembly process, fabricate the hardware and demonstrate the complete remote disassembly of the mine round. Continue the development of materials and system aging models. Complete the predictive model for the reliability of plastic encapsulated microcircuits in dormant storage. This is important because commercial specifications and test protocols do not accurately represent the long-term storage times and conditions relevant for DoD munitions.

(\$ 1.91 Million)

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| (U) B. <u>Program Change Summary</u> | <u>FY1999</u> | <u>FY2000</u> | <u>FY2001</u> | <u>Total Cost</u> |
|---|----------------------|----------------------|----------------------|--------------------------|
| Previous President's Budget | 13.007 | 14.786 | 14.790 | Continuing |
| Appropriated Value | 0.000 | 0.000 | 0.000 | Continuing |
| Adjustments to Appropriated Value | | | | |
| a. Congressionally Directed Undistributed Reduction | 0.000 | 0.000 | 0.000 | |
| b. Rescission/Below-threshold Reprogramming, Inflation Adjustment | (.454) | (.104) | (.120) | |
| c. Other | 0.000 | (.367) | 2.000 | |
| Current President's Budget | 12.553 | 14.682 | 16.670 | Continuing |

Change Summary Explanation:

(U) **Funding:** FY 1999 reflects reprogramming reductions. Funding changes in FY 2000/2001 reflect adjustments for inflation and the FY 2000 government wide recession.

(U) **Schedule:** N/A

(U) **Technical:**

(U) **C. OTHER PROGRAM FUNDING SUMMARY COST:** N/A

(U) **D. ACQUISITION STRATEGY:** N/A

(U) **E. SCHEDULE PROFILE:** N/A

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