Fiscal Year (FY) 2005 Budget Estimates Exhibit R-2, RDT&E Budget Item Justification							Date: February 2004	
Appropriation/Budget Activity RDT&E, Defense Wide/BA 3			R-1 Item Nomenclature: Joint DoD/DOE Munitions PE 0603225D8Z					
Cost ($ in millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	
Total PE Cost	18.124	24.648	23.319	25.256	25.552	26.015	26.012	
DoD/DOE Munitions/P225	18.124	24.648	23.319	25.256	25.552	26.015	26.012	

(U) A. Mission Description and Budget Item Justification:

(U) The Joint DoD/DOE Munitions Technology Program has the mission of exploration and development of technologies intended to bring about major improvements in non-nuclear munitions technology. A memorandum of understanding between DoD and DOE provides the necessary basis for long-term commitment of resources of the DOE and a similar long-term commitment of the enabling DoD support for this effort. The continuous fusion of DOE technology with Service needs has provided major advances in warfighting capabilities and plays a crucial role in the exploration, development, and transition of new technologies of interest to the Services. The program provides a unique opportunity for the collaboration of DoD and DOE scientists to explore technologies of programmatic interest to both departments, within a structured program of established Departmental reviews and milestones. The interdepartmental collaboration allows exchange of information and the focusing on achievement of goals of interest to the Department, utilizing the substantial investment in the scientific resources of the DOE. The budgeted program funds represented here are supplemented by additional matching DOE funds.

(U) Over the last three years, there has been an increased programmatic emphasis on developing technologies of particular value to counter-terrorism capabilities and asymmetric warfare. Initial successes have already emerged from this focus with products currently in the field. The increase in Budget for FY 2004 and beyond was designed specifically to focus additional program efforts on exploring and developing technologies to transform the operational capabilities of the warfighter. Two specific efforts were targeted for this increase: The first is the support of a new and rapidly emerging technology employing inert-loaded explosives which will enable precision lethality munitions; The second is the support of accelerated development of advanced initiation systems which will provide increased reliability, capability, and fieldability of Service munitions. The inclusion of precision lethality munitions within the Joint Program is significant from a number of points of view. The program goal is the development of the understanding as well as the demonstration of the capability for a precision lethality munition, which combines substantially increased lethality within a prescribed region, with a low collateral damage beyond that region. Other anticipated characteristics of the precision lethality munitions are a reduced size over current munitions and satisfaction of insensitive munition requirements. The attainment of this goal requires simultaneous developments in the multiple program areas of energetic materials, computations and modeling, composites, penetration and warhead technology. This integrated effort within the Joint Program is a new approach which we believe will speed the transition of new technology through the development process. This effort has the strong support of all the Services and Special Operations Command. The advanced initiation systems effort is intended to develop a capability for the rapid fabrication and evaluation of multi-point initiation systems, which are critical to miniature, adaptable output munitions. The capability will greatly reduce the time and cost to design, develop, and implement the required advanced initiation systems. All Services have needs for the miniature, highly reliable, and adaptable initiation systems targeted by this development effort.

(U) The program effort is divided into five technology areas of interest to Department munitions, each of which is described below. The names of some of the technology areas have been modified to better reflect the content of the projects contained within. In addition, some projects have been re-allocated among the technology areas between FY2003 and FY2004, to better describe the functional area within the munition that will benefit from the project output.

(U) Sensors and fuzing are a critical components in every Department munition system. A fuze must ensure personnel safety by preventing unintended weapon detonation, know when to allow arming of a firing mechanism, detect the target through the use of sensors, and initiate detonation when required. With a growing emphasis on hard target defeat, advanced fuze systems must be able to survive and function in increasingly higher-velocity, higher-g penetration environments. One method of surviving high-g environments is through the miniaturization, integration, and/or robust packaging of conventional fuze components such as detonators, switches, transformers, capacitors, and sensors. In support of this technology area this program continues to demonstrate advances in miniaturizing high-voltage Electronic Safe and Arm Devices (ESAD) through research and development of low-energy detonator / booster combinations and miniature capacitive discharge units (CDUs). This focus builds on recent advances in micro-detonic/energetic materials research, and MEMS Safe and Arm Devices (MEMS-SAD). Efforts in this portion of the program generally advance fuze technology development and ultimately provide the DoD and DOE with viable fuzing components for all weapons, particularly hard-target-defeat munitions (penetrators) and small, intelligent low-cost applications (artillery). Over the next five years this portion of the program will work toward demonstrating emerging technologies that support robust, intelligent fuzing that can survive and function in environments exceeding 30,000 G's. Advanced initiation technology is an enabler for the next generation of warheads that will be aimable, target adaptable, and survivable. This area is targeted for increased funding as described above.

(U) There is a growing need in the United States to develop energetic materials (EMs) that, when integrated into munitions, offer advantages of enhanced lethality against a variety of targets. Lighter and/or less bulky munitions significantly impact the logistics burden on military actions. Similarly, a decrease in hazard classification brought about by the use of insensitive energetic materials and better design will greatly decrease transportation and storage logistics costs. Smarter munitions, capable of selectable, differential output, are another boon to military agility. Hence, there is also need for advanced EMs that can be used in small-scale devices such as distributed fuzing systems. In addition, as the intended environments have become more severe, EM's must survive setback forces in guns and severe impact forces in hard-target penetration applications. Work in energetic materials was aligned with the recommendations from the DoD 2000 Weapons Technology Area Review and Assessment (TARA) and is coordinated with the recently established national initiative in advanced energetic materials. This aspect of the program is aimed at developing the next-generation of EMs that have increased energy density over those in our current inventory while remaining insensitive to extreme environments. An additional requirement is that the energy be released in an appropriate time domain to allow optimized coupling to the target. For enhanced lethal effects the energy must be released either in the detonation reaction zone, or early enough in the expansion so that it couples to impulse loading or sustains high temperatures. Material ingredients that contribute to energy release later than that offer no enhancement in lethality. A fundamentally new approach to increasing lethality while simultaneously reducing collateral damage is being investigated. Holding much potential for modern warfighting scenarios, this new material formulation provides increased performance while meeting insensitive munition standards. For microdevices suitable for distributed fuzing systems the requirement on energy release is very exacting in order to sustain reaction propagation in environments with extensive shock and heating losses. Like advanced initiation, advanced energetic materials are enabling technology for the next generation of weapon systems that will be safer, smaller and more lethal.

(U) The ability to accurately predict the behavior of weapons in their operating environment of extreme pressure, temperature, and velocity is essential to the development of lethal, accurate, and cost effective systems. To meet the needs of the DoD and DOE communities, there is a requirement for validated capabilities using high-performance computing hardware and software that are sufficient to carry out a broad class of continuum mechanics simulations where shock waves, nonlinear dynamics, and multi-material gas dynamics are important. In particular, this aspect of the program focuses on numerical and algorithmic improvements to enhance our problem solving capabilities for munitions development, advanced energetics, and target lethality predictions with significantly improved material models that accurately represent the material in dynamic states. Three general classes of codes offer solutions to the varied requirements posed by the defense community in the shock analysis regime. Eulerian shock physics tools are effective for a large number of conventional weapons and advanced energetics related simulations. Anywhere there is very large material deformation and turbulent mixing, Eulerian formulations are the most efficient. A second class of codes addresses the large, nonlinear dynamics that can be important for weapons design and development. Such Lagrangian calculations provide design information that complements information provided by the Eulerian shock physics codes. For example, many penetration problems involve detailed structural mechanics that are not appropriate for Eulerian codes. A third class of tools combines capabilities by using arbitrary Lagrangian-Eulerian (ALE) algorithms to solve the conservation equations appropriate for shock analysis. This class of codes performs a range of simulations such as penetration mechanics, thermal cook-off, and fragment impact where multi-physics phenomena descriptions are required across a wide range of time scales, which cannot be addressed adequately with either Eulerian or Lagrangian codes. These codes and associated validated material models represent the future in modeling complex dynamics encountered in a broad spectrum of applications across the defense community. To date, the Department utilization of these capabilities is primarily in the S&T community. It is desirable to extend developing modeling and simulation tools into the engineering design community and this program will continue to provide supporting computational tools.

(U) There is a worldwide trend to harden more military facilities. Increasingly, these are being buried in layered earth and concrete "cut and cover" constructions, tunneled into mountainsides, or mined into rock far beneath the earth's surface. Buried structures accounted for a significant number of targets attacked by our forces during the Gulf, Afghanistan, and Iraq wars, and much of our military planning is being devoted to defeating them. A major thrust of this program continues to be hard target defeat. As hard target weapons evolve, several technical issues need to be addressed.

Specifically, penetrators striking targets with obliquity or with high angles of attack experience violent dynamic responses that can fail their cases or interfere with the functionality of fuzes. Similarly, oblique, low velocity target impacts can result in ricochet, undesirable shallow trajectories, or bouncing out of the target. In general, new delivery vehicles tend to be smaller and faster, requiring smaller penetrators that carry less payload and must survive more stressing impacts. Developing improved penetrating weapons depends on a solid understanding of the physics of penetration as well as affordable materials and processes to execute new designs that require more strength and durability from the penetrator. Although we can predict penetration depth with acceptable confidence, there are some targets for which we have insufficient data and experience; consequently, predicting the path a penetrator will take and whether it will survive is much less certain. This program provides a fundamental penetration technology base that addresses many of these issues and enables our future strike weapons. Additionally, warhead concepts which greatly extend the current range of capabilities in speed and tailored target effects are being explored. With increasing emphasis and interest in defeating targets of military interest in civilian areas, and of defeating and neutralizing WMD facilities, the application of energy to target must be thoroughly controlled and understand. This requirement places need demands on warhead output, which are being pursued under this program.

(U) DoD and DOE efforts toward munitions lifecycle technologies including stockpile aging, surveillance, demilitarization and disposal are coordinated under the auspices of this program. The Department has a large and growing inventory of conventional munitions in its demilitarization stockpile. Currently, the stockpile includes more than 400,000 tons and it is expanding by about 70,000-100,000 tons per year. As the long term focus 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. The technologies developed in this portion of the program enhance DoD capabilities to field safe, cost-effective processes for disposal, resource recovery, and reutilization of munitions and munitions components. For an aged weapons stockpile that has not reached end of useful life, reliability and surety will change with time because of the age-related degradation of constituent materials. Existing stockpile assessment methods typically focus on addressing materials aging and reliability problems after they occur, rather than on anticipating and avoiding future problems or failure mechanisms. The predictive materials aging and reliability portion of this program is focused on improving our ability to understand, measure, predict, and mitigate safety and reliability problems caused by materials aging degradation in weapons systems. Together with complementary demilitarization technologies, this focus provides a base of scientific knowledge and understanding that enhances the Department's ability to efficiently support the late phases of weapon lifecycle. Efficient management of existing stockpile assets is an economically necessary precursor to weapon system modernization.

B. Program Change Summary:

	FY 2003	FY 2004	FY 2005
Previous President's Budget	18.623	25.011	25.351
Current FY 2005 President's Budget	18.124	24.648	23.319
Total Adjustments	-.499	-.363	-2.032
Congressional program reductions			
Congressional rescissions			
Congressional increases			
Reprogrammings			
SBIR/STTR Transfer			
Other		0.363	2.032

C. Other Program Funding Summary: N/A

Acquisition Strategy. N/A

Fiscal Year (FY) 2005 Budget Estimates Exhibit R-2a, RDT&E Project Justification								Date: February 2004
Appropriation/Budget Activity RDT&E, Defense Wide/BA 3				Project Name and Number Joint DoD/DOE Munitions PE 0603225D8Z				
Cost ($ in millions)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	
DoD/DOE Munitions/P225	18.124	24.648	23.319	25.256	25.552	26.015	26.012	

(U) A. Mission Description and Budget Item Justification:

(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 44 projects in warhead technology, energetic materials, advanced initiation and fuze development, munitions lifecycle technology, and munitions modeling and simulation. A specific Service laboratory sponsors each of these projects. The program is administered and reviewed by a Joint Technical Advisory Committee composed of members from the Army, Navy, Air Force, Special Operations Command, OSD, and DOE. Projects are peer-reviewed semi-annually by DoD Service Laboratory/Technical Center personnel in order to monitor technical excellence and ensure 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. After reviewing the program, the most recent Weapons TARA panel assessed the program as follows: broad range of products transitioned to DoD as a result of program efforts; effectively leverages DOE expertise and funding; critical computational tools provided to DoD; well integrated into

Service efforts; Technology Coordination Groups provide an effective forum for technical collaboration.

B. Accomplishments/Planned Program

Accomplishment/Effort/Subtotal Cost	**FY 2003**	**FY 2004**	**FY 2005**	
Initiation, Fuzing, and Sensors	3.111	5.70	4.690	

(U) **FY 2003 Accomplishments:**

(U) In FY 2003, improvement of electronic safing, arming and firing systems continued with a focus on miniaturization, cost reduction and shock survivability for hard target penetrators. This year, miniaturization of the next generation microCDU continues with modeling of the discrete electronic components. The current design has a package volume of 0.030 in^3. The components were assembled and mounted onto a CDU flex cable configuration designed to wrap around the ceramic capacitor, operated at 1000 V, and successfully demonstrated to hold off 1500V. In late FY2002 detonation of HNS or CL-20 explosive with this microCDU design will be demonstrated. In support of a viable fuze industrial base, work is ongoing with Raymond Engineering and other suppliers on improving the manufacturing process for chip detonators and characterizing their performance. Nanostructured Multi Layer (NML) technology has the potential of reducing the size of a fireset capacitor by a factor of 10 to 100. Towards this goal, a total of 68 NML one, tow, three, and four capacitors, of four different configurations were fabricated and are currently awaiting testing. This is the first important step towards the fabrication of an NML capacitor of greatly reduced volume. As low voltage fuze architectures are developed, it is anticipated that the ability to physically move or block fire train elements (e.g. micro energetic materials) will be a primary feature of out-of-line systems. In support of these architectures, the ability to integrate micro energetic materials with MEMS devices will become a crucial technology. Accordingly, an effort is in place to learn how to preferentially load or coat simple MEMS structures with film energetic materials. Specifically, methods for patterning explosive materials using both reactive ion etch and lift-off techniques were successfully studied. As a result of this initial inquiries, a dedicated energetic material deposition system is being has been installed at Sandia which will enable the production of microenergetic devices by sequential CHNO deposition. Towards the program goal of demonstrating a prototype ESAD in a high-velocity penetrator in FY2003, characterization of detonators, capacitors, and switches in shock environments for application to hard target munitions was completed. A principal issue in multipoint initiation systems remains determination of the physical reasons for power-sharing inefficiencies and/or current oscillations in multipoint slapper arrays. In order to address this issue, current distribution was measured for incorporation into a validated electrical model that can be used to optimize multipoint array design. Support and development of the knowledge base tool for preservation of advanced initiation technology continued with an expanded scope that included other fireset components beyond detonators.

(U) In the sensors are, there is uniquely important work on precision guidance based on synthetic aperture radar (SAR) technology. While currently employed in UAVs, there is a need for a much reduced weight, reduced cost SAR, termed miniSAR. In 2003, the designs for the key components were completed and fabrication begun.

(U) <u>FY 2004 Plans:</u>

(U) A new project is starting with a focus on millimeter scale initiation and detonation. This work will attempt to understand the behavior and response of thin layers and small quantities of explosives, as are required for all MEMS based fuzing and microfiresets. This is a key enabling technology for miniature munitions and remains a largely unstudied field. Specific work plans for 2004 include measurement of run to detonation and failure diameter studies on HNS-IV, CL-20 and high surface area PETN. Development and demonstration of improved components and architectures for robust, low-cost, miniature safing, arming and firing systems will continue. Individual control of multiple initiation sites within a warhead using silicon fireset circuits will be demonstrated. Initial testing of extrudable explosive formulations will be completed and evaluation will continue and commercial sources for a robust manufacturing technology base will be explored. An integrated capacitor and switch in a single package will be demonstrated for use as a next generation microfuze component. Current state of the art micro-fuze technology will be applied and focused on Special Operations Forces (SOF) requirements in order to enhance and expand SOF capabilities in various mission scenarios. The latest miniaturization technology will be transitioned to production-type facilities and to the Services in order to begin exploitation. The study to understand and predict instabilities in multiple-slapper, highly miniaturized systems will be completed towards the design of highly reliable and uniquely flexible ordnance systems. Experiments will be performed that will enable development of the theory and models of explosive behavior in very small geometries (microdetonics). Materials resulting from new formulations and the sol-gel process will be characterized and performance tested. MEMS devices will be characterized and tested in stressing high-g environments. Complete most subsystems of the miniSAR and form an industrial partnership to develop components, where appropriate.

(U) FY 2005 Plans:

(U) Conduct tests to demonstrate and evaluate the utility of rapidly prototyped multipoint initiation systems to enhance the performance of munitions. Evaluate reduction in development cycle time and cost achieved by rapid prototyping, as well as improvement in multi-point bridge performance gained from careful control of individual bridge geometry. Continue component miniaturization and cost reduction efforts. Demonstrate a packaged microtransformer for use in miniaturized munitions. Complete streak photography and VISAR diagnostic measurements for improved slapper detonator efficiency. Perform Detonation Shock Dynamics (DSD) analysis of initiation system transfer into a main charge. Implement viable multipoint diagnostics, such as magnetic probes or PVDF gauges, onto an array for use in warhead evaluation tests. Continue Development of MEMS CDU components. Demonstrate a packaged MEMS-SAD. Complete set of environmental tests on second generation Silicon Fireset assemblies. Implement a 6 kV single n-MCT switch sufficient for initiating a multipoint array. Design a minimum energy slapper and extrudable explosive system for use in adaptable warheads. Towards a miniature, optically charged fireset, complete development of very small 10 layer capacitors and begin integration of nanostructure multilayer capacitor and switch. Continue detonator designs requiring reduced micro joules of stored energy to fire. Complete prototype impact triggered MEMS fuze. Transition rapid prototyping technology. Complete and fly the initial phase 1 version of miniSAR.

Accomplishment/Effort/ Subtotal Cost	FY 2003	FY 2004	FY 2005	
Energetic Materials	5.573	6.214	6.750	

(U) **FY 2003 Accomplishments:**

(U) Concern from the DoD 2000 Weapons TARA regarding the need to maintain weapon lethality as weapon and platform size decrease were addressed in efforts to synthesize, characterize and scale-up new energetic materials with increased or tailored performance and decreased sensitivity. The development and characterization of new insensitive and new high-energy, high power materials continues with synthesis based on theoretical molecular design and insight. A host of new molecules are synthesized and evaluated each year. Those with promise are shipped in small quantities to DoD labs for further test and evaluation. Potentially significant output from this work is high nitrogen molecules as burn-rate modifiers for gun propellants, with the added attribute of reduced barrel erosion. An example is LLM-105, an attractive new booster material, which is being characterized in booster-size samples to evaluate its initiation threshold, cold temperature performance, and density and flyer size effects. Efforts are underway in this program to exploit opportunities in nano-energetics by developing nano-structured and engineered energetic materials, including sol-gel derived materials, and evaluating their effectiveness and utility for warhead applications. Energetic nanocomposites are of great interest as reactive materials, and accordingly have particular processing requirements. These were demonstrated as possible during 2003. Sol-gel chemistry was also applied to a method for producing high surface area nanometric WO_3. A new effort in 2003 was the study of the formulation of dense inert metal explosives (DIME), which have significant near-field damage capability. The materials combine explosives with metal powders in a uniform mixture. A cast-sure system of TATB and tungsten was developed and tested. Safety tests of the material were conducted successfully.

(U) Cheetah is a thermochemical code which predicts the performance of new explosives and is invaluable in explosive formulation efforts and is widely used throughout the Department for explosives and propellant analyses. In FY 2003, Cheetah underwent a major re-organization into a component architecture, which will simplify the development and maintenance of the code in future years. Also, significant improvements were made to the scientific capabilities of the code with the implementation of new chemical kinetics, allowing for real gas equations of state to be used. Efforts to develop and validate computational tools for predicting munition system response to operational threat and computational capability. The first generation of simulation tools for munitions response to accident environments has been exercised against test data to validate the codes and expand their ability to predict weapon system performance and response in accident situations. Experiments were run in 2003 using strand burners and scaled thermal explosion experiments to benchmark ALE3D. Also, the same code was used to evaluate laser lethality of munitions, subject to attack with high power lasers. Results indicate different mechanisms are important for laser heating, leading to unique results. Experiments to determine mechanical properties of both fielded high explosives and their constituents continued for development and validation of high explosive mechanical response models. Specifically, PBXN-110 and Al-Teflon materials were characterized in support of ongoing Navy applications. The creation of new HEDMs continued, along with the development and implementation of accurate techniques for determining crystal structure and energy content of the newly synthesized materials. While progress is slow in this difficult field, progress was made in characterizing and determining energy content in new laboratory-created extended solid materials.

(U) FY 2004 Plans:

(U) Efforts to synthesize, characterize and scale-up new energetic materials with increased or tailored performance and decreased sensitivity will be continued. Coordination with the national advanced energetics initiative will also continue towards re-invigorating the energetic materials skill base within the Department. A summary report documenting the synthesis and scale up of LLM-105 as a booster explosive will be distributed to the energetics and fuzing communities in completion of the effort. FY 2003 advances in sol-gel metal oxide chemistry will be applied and focused on applications development and testing in support of specific Service requests for readily processed reactive materials and high performance thermitics. Energy and performance measurements of CO-derived and nitrogen HEDM's macro-samples will be completed and the synthesis of additional extended solid HEDMs will be explored. In FY 2004, Cheetah 4 will be released to the DoD community for performance predictions of an extended set of energetic materials. Development of ignition phenomenology models and design of ignition location experiments will be completed in support of the effort to validate and expand codes for predicting weapon system performance and response in accident situations. The effort to preserve and transition energetic materials technology generated by the community will continue with the distribution of an extended APEX database that will include over 500 energetic materials of different molecular structure. Support of enabling energetic materials technologies for low collateral damage munitions will expand with the development of near-field and far-field product equations of state for the baseline explosive fill selected in FY 2003. Energetic materials requirements for SOF focused microfuze technology activities will be supported through testing of different nano-fuel/oxidizer formulations and incorporation of multi-layer energetic materials into propagation micro-channels.

(U) FY 2005 Plans:

(U) Continue development of nanoscale, microscale and mesoscale energetic materials with enhanced performance that are less sensitive and cost effective enablers for defense transformation. Demonstrate and characterize sensitivity and burning of hydrogen and nitrogen mixtures with nano-metals. Continue processing, scale-up, and performance characterization of low collateral damage energetic materials. In the area of high nitrogen energetic materials, continue measurements of burn rates and pressure-time histories for burning HN mixtures with nano Al, metals, and MIC; complete performance and sensitivity testing of azo-formamidines. Continue updating APEX explosives database on an 18 month cycle. Complete synthesis of ANTZ based target molecules as a new insensitive energetic material ingredient and synthesis precursor. Complete sol-gel metal oxides weaponization. Complete analysis of Navy fast cookoff experiments. Deliver high explosive grain scale continuum model for use in predicting the performance of plastic bonded explosives.

Accomplishment/Effort/ Subtotal Cost	**FY 2003**	**FY 2004**	**FY 2005**	
Computational Mechanics and Material Modeling	2.560	6.095	5.487	

(U) **FY 2003 Accomplishments:**

(U) Predicting the behavior of weapons in their operating environment is essential to the development of lethal, accurate, and cost effective systems. 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 direct 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. Additionally, a new effort in FY02 commenced to study fragmentation and dynamic fracture of materials. Highly diagnosed experiments were conducted to generate a data base to benchmark computational models. Also, in 2003 a new emphasis was initiated on multiphase flow simulation. This area is of importance to the modeling of explosive mixtures heavily loaded with particulates, as well as in the prediction of the dispersal of agents introduced into an airstream. Blast loading of structures, applicable to structural integrity of dams subject to attack was another area of new emphasis. Sample problems were run in both of these new areas.

(U) **FY 2004 Plans:**

(U) Note that the large increase in funding for this technology area stems from the re-allocation of projects which previously were located in the Energetic Materials area. The increase in funding level does not indicate significant increase in activity. The new projects in this area relate to the modeling of the mechanical properties of explosive, polymers, and the generation of test data to validate the computational models. The development of Eulerian, Lagrangian, coupled and ALE codes relevant to the design and evaluation of munitions will continue. 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. A particular growing effort in this year is the development of a mixed phase flow calculational capability to describe inert particle loaded explosives. This capability is essential to the understanding of low collateral damage phenomena.

(U) **FY 2005 Plans:**

(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 mixed phase flow problems. Continue to support the transition of these tools, the training, and consulting for the DoD user community. Complete tensile plasticity and damage model extension for use within warhead design codes. Towards a robust, mesh free warhead design tool, begin extension of Dual Particle Dynamic (DPD) methodology to three dimensions. Complete integration of CTH and NEVADA design tools. Complete fragment explosive initiation modeling in support of DoD initiatives. Continue advanced material model implementation for warhead design and evaluation. Validate predictive capability for low collateral damage munition performance and effect..

Accomplishment/Effort/ Subtotal Cost	**FY 2003**	**FY 2004**	**FY 2005**	
Warhead Technology & Integration	4.650	4.034	3.664	

(U) **FY 2003 Accomplishments:**

(U) In FY 2003, a suite of oblique penetration tests was begun. Through the use of a newly-developed 3-axis accelerometer, initial impact off-normal conditions will be utilized to benchmark computational models. Case materials research has been underway for a number of years and a report will be published in 2003 documenting findings on various materials and processing investigated. A new penetrator steel, ES-1, has been developed as a low-cost alternative to high-alloy steels such as HP-9-4-20m AF1410, and AerMet 100. ES-1 is scheduled for use in the next generation of BLU-113. Many well-controlled benchmarking experiments are being conducted for comparison with code predictions to evaluate modeling capability for oblique impact, varied geologic materials, and the effect of target diameter. A jointed penetrator concept was investigated as a future concept offering lower cost and much reduced production time. The cluster charge concept, which originated several years ago, was extended to include performance measurements against various in-situ geological targets, including tuff, limestone, and granite. Effects of target strength and porosity were documented. A project initiated in 2002 to provide a low collateral, discriminate lethality capability is continuing. This project includes and integrates the component technologies of DIME and fiber composite case structures to provide the discriminate lethality capability. Contributions from across the program are required for the development of this new capability and the integration of the efforts is carried out as part of Warhead Technology and Integration Technical area. Integration is seen as a vital element of all future munitions, with its own set of unique issues not seen in discrete component development. In recognition of this fact, the title of this technology area was modified.

(U) FY 2004 Plans:

(U) Integration of all the components necessary for a low collateral damage munitions concept will occur. Energetic formulation, composite, case, and performance predictions based on modeling to date, will be combined in this effort. Near term applications of this technology are believed possible based on these tests. Efforts to provide enabling technologies for defeat of hardened military targets will continue in FY 2003. Dynamic compression studies of ES-1 and high-alloy steels will be completed and documented. Three axis oblique penetration experiments into concrete targets will generate a data base for the DoD and DOE communities for code and model benchmarking. The focus will be on obtaining data that reveals the dynamic rotations of the penetrator during entry and the resulting trajectory. The data will be provided to the DoD community for use in validating and benchmarking hard target design tools. Several new tasks will be initiated to look at penetration in multi-layer targets, angle of attack effects on penetration and payload survivability, and a boosted penetrator concept as a means to increase penetration depth. The development and integration of the computational, explosive, penetration, and composite material technologies required for an enhanced alternative to the use of inert munitions against soft targets in urban areas will be accelerated. Low collateral versions of existing bomb, such as Mk 82, are being fabricated and prepared for comparative test evaluation. The processing contribution of metal liner materials to enhanced performance will continue with the emphasis on studying special grain boundaries. Previous work in the commercial arena has demonstrated significant mechanical and corrosion resistance properties are achievable through control of grain boundaries. Temperature measurements of shocked materials will be applied to a variety of metals shocked to various stress states. Focus will continue on 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. The simulations of the Ta liner test-bed experiments will be continued in order to assess the utility of the new materials models in the warhead design process.

(U) FY 2005 Plans:

(U) Continue low collateral damage verification and validation testing in comparison with current best baseline munition. Use test data to evaluate simulation capability in predicting target damage. Continue the study of advanced hard target penetrator concepts and adapt designs to state-of-the-art materials and manufacturing methods. Complete instrumented oblique penetration tests using the 3 axis data recorder. Complete target size penetration tests aimed at reducing the cost of penetration tests for the community by obtaining evidence of a size scale effect. Continue target diameter benchmarking efforts in support of size-scale effect testing. Continue improvements in modeling of target entry dynamics and trajectory predictions via field testing and analysis. Complete characterization of low cost, high hardness candidate penetrator materials. In the area of design improvements for hard target penetrators, complete survivability design concepts. Continue improvements to the hard target response predictive capability established in the Peridynamic design tool. Complete push control studies using alternative reactive warhead materials. Continue efforts towards an FY 2006 demonstration of energy coupling enhancement through initiation.

Accomplishment/Effort/ Subtotal Cost	**FY 2003**	**FY 2004**	**FY 2005**	
Munitions Lifecycle Technologies	2.230	2.605	2.728	

(U) **FY 2003 Accomplishments:**

(U) Femtosecond laser cutting of energetic materials has been successfully demonstrated in the 10 kg explosive tank. This is significant because it gives us the capability to cut systems containing larger amounts of explosives and thus, makes it possible to test mock-ups of weapons systems as well as complete systems. In addition, the process has been successfully extended to cutting propellants; this is a significant milestone that opens the possibility of using the femtosecond laser to demilitarize rocket weapon systems. Determination of a portion of the optimum cutting parameters, safety limits, and geometry limits for munitions related materials and high explosives was also completed. As a result the project is considered mature for this program, with technology available for transition to DoD demil programs. Work on the robotic workcell focused on adapting the system to the disassembly of Adam mine rounds and completing the vision and control algorithms, as well as the associated hardware, necessary to demonstrate completely automated disassembly of a cluster munition with safing of the individual submunitions. This goal was attained in FY 2003. In the area of ageing and predictive means for material lifetimes and failure. The development of materials and system aging models continued with a focus on predicting the reliability of solder interconnects, plastic encapsulated microcircuits, propellants, and adhesive joints. A project initiated to characterize the particle emissions generated from open burn/open detonation (OB/OD) events characterized background signatures for a variety of aerosols including common atmospheric aerosols, biological background and a large number of powders. The result of the work will be an instrument which can satisfy present and future anticipated regulatory requirements on particle emissions from OB/OD events, with a minimum of false positives. Having completed the signature development phase, emissions from small scale munitions were recorded. A new start project was the development of a stand-off sensor for monitoring the position of the receding surface of propellant during rocket motor wash-out. The benefit of the tool is faster and safer washout of large rocket motors.

(U) FY 2004 Plans:

(U Mid-scale testing of sensors that can detect particle emissions in explosive events will commence. The small and mid-scale sensor test results will be used to generate a data base and analysis tools for standoff identification and specification of particles generated in detonation events. Dissassembly and handling of ADAM mine projectiles will be demonstrated. Adapt the robotics technology to the M77 grenade and demonstrate removal of MLRS M77 grenades from a warhead section. The technology for standoff monitoring of OB/OD events at DoD demilitarization sites will be transitioned to a commercial partner. In the predictive materials aging and reliability area, measurements of the electrical response of dormant storage munition electronic components will commence. Under the aging of propellants task, continue to participate in the service life predictive technology (SLPT) program. This will consist of improved characterization of critical chemical and physical aging processes in composite propellants, and formatting that information into constitutive models for into predictive 3-D reactive-diffusion codes. The particulate emissions identification project will move to actual large-scale open-air detonation events, where soil samples near the event will have been characterized to provide a baseline signature.

(U) FY 2005 Plans:

(U) Complete real time particle size and composition analysis open air testing. Complete isothermal fatigue experiments for solder interconnect reliability studies. Transfer electronic corrosion predictive model to Service demilitarization efforts.

Continue identification of critical DoD electronic components susceptible to corrosion failure. Complete studies aimed at determining propellant thermal decomposition kinetics. Continue analysis of DoD aged samples and participation in Predictive Service Life Technology program reviews as requested. Complete MEMS reliability monitor verification tests. Complete testing of stand-off sensor for rocket motor demilitarization. Complete explosive combustion studies for predicting toxic emissions in OB/OD events. Prototype, design, and fabricate M77 grenade handling and safing hardware. Continue identification and analysis of non-plastic encapsulated critical DoD weapon components. Measure age dependent weapon adhesive joint toughness at various temperature levels and high humidity. Apply interfacial fracture mechanics methodology to existing DoD/DOE weapon systems. Continue HX-874 propellant binder aging studies.

C. Other Program Funding Summary: N/A

D. Acquisition Strategy: N/A

E. **Major Performers:** The work is performed in-house at the three DOE National Laboratories responsible for nuclear weapons RDT&E: Lawrence Livermore, Los Alamos, and Sandia National Laboratories.