RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 2002
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense Wide/BA 2	**R-1 ITEM NOMENCLATURE** High Energy Laser Research **PE 0602890D8Z**

COST *(In Millions)*	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Cost to Complete	Total Cost
Total Program Element (PE) Cost	29.723	35.231	39.310	42.711	46.151	49.652	53.200	Continuing	Continuing
High Energy Laser/P890	29.723	35.231	39.310	42.711	46.151	49.652	53.200	Continuing	Continuing

(U) A. Mission Description and Budget Item Justification

(U) BRIEF DESCRIPTION OF ELEMENT

(U) This program element funds High Energy Laser (HEL) applied research aimed at translating fundamental scientific knowledge into proof-of-concept solutions relevant to HEL systems. HEL weapons systems have many potential advantages, including speed-of-light time-to-target, high precision, nearly unlimited magazine depth, low cost per kill, and reduced logistics requirements because of no need for stocks of munitions or warheads. As a result, HELs have the potential to perform a wide variety of military missions, including some that are impossible, or nearly so, for conventional weapons. These include interception of ballistic missiles in boost phase, defeat of high-speed, maneuvering anti-ship and anti-aircraft missiles, and the ultra-precision negation of targets in urban environments with no collateral damage. Research conducted under this program element develops the technology necessary to enable these and other HEL missions.

(U) This program element is part of an overall DOD initiative in HEL science and technology being conducted by the HEL Joint Technology Office (JTO). The goals of this HEL JTO funded research are to provide the technology to make HEL systems more effective and also to make them lighter, smaller, cheaper, and more easily supportable on the battlefield. In general, efforts funded under this program element are chosen for their potential to have major impact on multiple HEL systems and on multiple Service missions. As a result of this focus and of close coordination with the military departments and defense agencies, this program element complements other DOD HEL programs that are directed at more specific Service needs.

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(U) A broad range of technology is addressed in key areas such as chemical lasers, solid-state lasers, beam control, optics, propagation, and free-electron lasers. Research is conducted by Government laboratories, industry, and universities. The program element funds theoretical, computational, and experimental investigations. In many cases, these three types of investigations are combined under a single effort, thereby creating synergistic effects between various scientific approaches, and greatly enhancing the potential for breaking through the technology barriers that currently prevent HELs from being fielded as viable weapon systems. DOD intends to transition successful systems concepts developed under this program element into advanced technology demonstrations for particular mission needs.

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(U) <u>Project Number and Title: P890 High Energy Laser</u>

(U) <u>PROGRAM ACCOMPLISHMENTS AND PLANS</u>

(U) <u>FY 2001 Accomplishments:</u>

(U) FY 2001 this program element funded 30 different competitively selected technical efforts, totaling $29.767 million, divided into the following areas:

- Solid State Lasers ($8.715 million)
- Beam Control ($7.530 million)
- Chemical Lasers ($6.300 million)
- Mission and Systems Analysis Studies and Program Management ($3.528 million)
- Novel and Innovative Technologies ($2.050 million)
- Lethality ($1.350 million)
- Free Electron Lasers ($0.250 million)

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(U) Solid-state lasers have potential as future HEL weapon laser devices because they require only electrical energy in order to run, thereby greatly simplifying systems engineering and supportability. These devices have the potential to eliminate the need for munitions resupply on the battlefield in key mission areas such as tactical strike and air defense. Solid-state-laser technology development emphasizes combining fiber-laser modules, scaling up power in diode-pumped lasers, and testing new systems concepts. Results of these activities are key to developing solid-state lasers with weapons-class power levels. Examples of FY 2001 solid-state-laser technology-development activities include the following:

- Developing 1 kilowatt-class fiber-laser amplifiers and designing and experimentally testing methods for coherently phasing groups of fiber-laser amplifiers to increase total output power to the 10 to 100 kilowatts level
- Developing new high-power, high-reliability diode-pumped laser power supplies for fiber lasers and amplifiers, to withstand the thermal and material stresses of sustained high-power operation at powers in excess of 1 kilowatt, thereby providing a cornerstone for the development of future lighter, more lethal, more affordable, and more supportable solid-state-laser HEL weapon systems
- Developing, fabricating, and demonstrating a design for a thin-disk (as opposed to bar-like) solid-state laser at a 300 to 500 Watt power level, as a step toward the future development of 8 kilowatt disk-based laser devices, thereby potentially easing thermal-management problems on future high-power solid-state lasers
- Developing, fabricating, and demonstrating amplifiers and correcting mirrors as a means of mitigating the thermal distortions on 300 Watt average power/5 kilowatt peak power solid state lasers, thereby taking an initial step towards scaling the technology to 100 kilowatt and enabling extremely high-power solid-state lasers

(U) Beam-control technology development centers on those technologies directly applicable to surface, air, and space mission areas, as well as development of supporting technologies. Results of these activities will be transitioned to near-term HEL systems and will also serve to enhance the HEL-related technology base and industrial capability. Examples of FY 2001 beam-control technology development activities include the following:

- Developing high-power coatings and substrates, thus reducing the weight and increasing the affordability of HEL subsystems
- Conducting ground-to-space compensated laser beam propagation from a weapons-class aperture (e.g., several meters), thereby demonstrating key Ground Based Laser technologies for future space and missile-defense applications
- Developing advanced adaptive-optics component-level and subsystem-level technologies and control methodologies, thereby contributing to increasing the effective range of future HEL weapons

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- Designing, fabricating, and testing novel concepts for adaptive optics, which promise to greatly decrease complexity and weight and increase affordability while still allowing HEL weapons to compensate for atmospheric turbulence
- Designing and fabricating new optical wavefront sensing devices that operate even in conditions of extremely high turbulence, thereby allowing beam-control subsystems to operate effectively even at low altitudes (e.g., for tactical laser systems)

(U) Chemical-laser technology efforts concentrate on developing improved predictive and design capabilities, new chemical-laser concepts, and higher performance and more supportable chemical-laser technologies. Despite the fact that chemical lasers are the most mature of the HEL laser device technologies, further technology development has the potential to greatly enhance their viability as weapon systems. Results of these activities will result in chemical lasers that are lighter and more affordable. Examples of FY 2001 chemical-laser technology-development activities include the following:

- Developing more sophisticated computational models for accurate performance prediction, thereby greatly improving design capabilities for future Hydrogen Fluoride/Deuterium Fluoride (HF/DF) and Chemical Oxygen Iodine (COIL) chemical lasers, particularly in the critical area of mixing nozzle design
- Designing, testing, and fabricating advanced mixing nozzles on HF/DF laser devices, thereby improving performance, reducing weight, and increasing effective magazine size on future space-based and ground-based HEL weapon systems
- Installing and testing a 20 kilowatt closed-cycle (sealed exhaust) COIL device as a means of assessing closed cycle COIL performance and supporting design of future closed-cycle chemical lasers, thereby offering the potential for chemical lasers that can reuse their chemical supplies, which greatly improves their supportability
- Designing, fabricating, and testing a novel means of delivering iodine chemicals to a COIL laser system in a way that eliminates the need for complex chemical tanks, thereby reducing weight and increasing reliability of future airborne chemical-laser-based HEL weapon systems, as well as simplifying iodine-associated logistics requirements

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(U) This program element funds two detailed studies that examine potential military missions for which HELs present unique solutions because of their inherent characteristics (i.e., speed-of-light, possibility of graduated effects, precise target selectability, nearly unlimited magazine size, reduced logistics requirements, etc.) as compared to today's conventional weapons. These studies are being used to focus the investment strategy for technology development. Additional activities of a programmatic nature that are funded by this program element include the operation of the Joint Technology Office (JTO), moving the JTO to Albuquerque, New Mexico, and funding several workshops designed to bring together experts for exchanges of ideas and gathering input for investment strategy development.

(U) Novel and innovative efforts are aimed at cross-cutting and revolutionary topics. Examples of FY 2001 novel and innovative efforts include the following:

- Developing and testing laser thermal-management concepts using a new two-phase, mist-cooling technique, which promises to greatly increase capabilities for removing waste heat from laser systems, thereby removing a technology barrier to extremely high-power lasers
- Developing the theory behind gamma-ray lasers, which could potentially offer different means of damaging targets using non-optical (i.e., gamma-ray) beams of energy generated via nuclear excitation as opposed to electronic excitation, which is the traditional method for creating laser light
- Providing support to the educational community for the specific purpose of sponsoring HEL-related science fairs, funding undergraduate and graduate programs in HELs, and including HEL topics in high-school and college curricular, thereby building the future HEL workforce

(U) Lethality technology development concentrates on developing a strong scientifically based understanding of laser kill mechanisms so that HEL systems can to optimized to produce the maximum kill probability for the minimum system size and cost. Examples of FY 2001 Lethality activities include the following:

- Developing theory and conducting experiments to improve the capability to model the interaction between extremely short laser pulses and various classes of electronic and structural materials, thereby enhancing lethality and damage assessment and countermeasures of targets when struck by HEL pulses

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- Developing and validating a three-dimensional, time-dependent, particle-based computer code that will more accurately predict damage levels at much lower computational costs, thereby ultimately reducing the cost of HEL systems design

(U) Free electron laser (FEL) development concentrates on building the FEL technology base with the overall objective of making the FELs more lethal, smaller, and lighter. Specifically, the FY 2001 FEL activities included the following:
- Designing and testing new technology for using permanent magnets on FELs, which simplify FEL design and increase affordability because permanent magnets eliminate the need for costly electromagnets

(U) FY 2002 Plans:

(U) Pursuant to Congressional direction the DOD is developing a comprehensive, prioritized investment plan for HEL science and technology. This investment plan is being developed by the HEL JTO, in coordination with the military departments and the defense agencies. The plan, which was completed by the beginning of FY 2002, will form the basis for the expanded work to be conducted under this program element in FY 2002 and beyond. Although the plan is not yet completed, the broad outlines of plan are becoming clear. Work will be conducted in solid-state lasers, free-electron lasers, chemical lasers, lethality, atmospheric propagation and compensation, lightweight deployable optics, beam control, chemical lasers, optical components, and modeling and simulation.

(U) Solid-state-laser work will focus on phasing of fiber lasers, the design and manufacture of reliable diode lasers as pump sources, and the thermal control of laser media.

(U) Free-electron-laser (FEL) work will focus on technologies to scale to high power and technologies to permit FELs to be fielded on military platforms.

(U) Chemical-laser research will include efforts to develop COIL lasers appropriate for space-based and tactical applications.

(U) Lethality work will develop a firm scientific understanding of the relative advantages of repetitively pulsed and continuous-wave lasers for defeating different targets of interest.

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(U) Atmospheric propagation and compensation will concentrate on understanding atmospheric limitations in low-altitude tactical scenarios and on developing advanced adaptive-optics technology to increase lethal range in these scenarios.

(U) A new effort will be initiated in lightweight, high-power deployable optics to reduce system weight while increasing laser intensity on target for space-based and other HEL systems.

(U) Beam-control efforts will focus on developing novel techniques, such as phased-array beam control and electronic beam steering, to reduce system size and weight and enable new system configurations (e.g., a conformal configuration on an aircraft).

(U) Advanced components—detectors for tracking systems, high-power coatings, optical substrates, wavefront sensors, deformable mirrors—will be developed to improve HEL system performance and to help protect and enhance the fragile manufacturing base in this critical area.

(U) Modeling and simulation efforts will be increased with the goal of providing a fully realistic model of end-to-end system performance, from birth of photons in the laser to their death at the target, thereby improving the design of HEL systems and reducing the need for expensive field testing.

(U) It is expected that many of the 30 projects begun in FY 2001 will continue in FY 2002, as will mission-analyze efforts. Continuation a project will be contingent on the project's success in FY 2001 and on its relevance to the goals of the investment strategy.

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(U) <u>FY 2003 Plans:</u>

(U) This program element will execute applied research under a comprehensive, prioritized investment plan for HEL science and technology. This investment plan was developed by the HEL JTO, in coordination with the military departments and the defense agencies. The plan, which was completed and approved by the end of FY2001, forms the basis for the expanded work to be conducted under this program element in FY 2002 and beyond. Work will be conducted in solid-state lasers, free-electron lasers, chemical lasers, lethality, atmospheric characterization, advanced optics, beam control for tactical scenarios, beam control components, and modeling and simulation. The investment strategy will continue to be refined, and the results of earlier mission-systems-technology studies will be considered for inclusion in this ongoing refinement process. Major, but not necessarily exclusive, emphasis will be placed on the tactical mission-type scenarios and applications in which HELs can contribute. Some efforts will also be directed at critical technologies that contribute to meeting the needs of strategic mission-type scenarios and applications. The major technology areas are:

(U) Beam Control Component Technology will be developed to improve HEL system performance and to help protect and enhance the fragile manufacturing base in this critical area. Specific objectives include: (1) developing windows, coatings, aperture-sharing elements, deformable mirrors, wavefront sensors, etc., (2) developing sensitive, low-noise focal plane arrays of appropriate sizes and operating at appropriate wavelengths for wavefront sensors and trackers, and (3) nurturing and enhancing the design, manufacturing, and testing base for beam-control components.

(U) Atmospheric Characterization for Tactical Scenarios will continue concentrating on understanding atmospheric limitations in low-altitude tactical scenarios. The payoff will be increased lethal range in these optically stressing scenarios. Specific objectives include: (1) making precise absorption measurements at HEL weapon-relevant wavelengths, (2) measuring and assimilating information on turbulence, aerosol scattering, and other optical effects in environments relevant to tactical HEL systems, and (3) developing real-time characterization tools to assist with HEL weapon system mission planning and operational employment.

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(U) Tactical Beam Control technology development efforts will seek to provide critical technology options for use in tactical scenarios on tactical platforms such as aircraft, ground vehicles, and maritime platforms, thus enabling the advantages of HELs to be applied in a wide variety of military operations. The expected payoffs from these efforts are validated beam control techniques to enable a whole new class of Army, Navy, Air Force, and Marine Corps tactical HEL systems. Specific objectives include (1) developing techniques for pointing and tracking in cluttered tactical backgrounds, (2) developing thermal blooming and turbulence compensation in tactical scenarios, and (3) demonstrating beam control on appropriate tactical platforms.

(U) Advanced Optics technology development will seek to extend the state-of-the-art in lighter weight, nonconventional approaches to adaptive optics systems. The potential payoffs are large reductions in overall HEL system weight and significant improvement in the ability to correct for stressing atmospheric aberrations, particularly for space-related applications. Specific objectives include (1) developing large, lightweight deployable optics and (2) developing practical nonlinear or other nontraditional adaptive optics.

(U) Solid-state-laser work will focus on developing technologies needed to make solid-state-lasers of high enough power, reliability, and affordability to make them viable candidates for HEL weapons applications. This work may also include, as a stepping stone, the development of moderately powered (i.e., 10-20 kiloWatts) illuminator laser technologies. The anticipated payoff for this work is the demonstration of the scalability of solid-state-lasers to weapons-class power levels. Specific objectives include (1) developing reliable, low-cost diodes for pumping lasers, (2) developing techniques for combining the output beams of laser modules, and (3) developing thermal-management techniques adequate for continuous wave or high-duty-cycle solid-state-lasers.

(U) Chemical-laser research will include efforts to develop and demonstrate closed-cycle chemical lasers, especially COIL-derived lasers, appropriate for space-based and tactical applications. The anticipated payoffs are tactically-suited chemical lasers of high power that are supportable on the battlefield. Specific objectives include (1) optimizing performance of chemical feed systems, mixing nozzles, exhausts, and other components, (2) developing and testing new processes and chemistries for running chemical lasers using a closed as opposed to open architecture, and (3) developing means of regenerating chemical laser fuels so they can be reused.

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(U) Free-electron-laser (FEL) work will focus on technologies to scale to high power and technologies to permit FELs to be fielded on military platforms. The expected payoff is the demonstration of critical FEL technology to support a Navy decision to proceed with weapon-class FEL development for shipboard demonstration. Specific objectives include (1) developing high-current photo-injectors, (2) developing new, high-efficiency wigglers, and (3) designing advanced resonators, to include optics and coatings, for high-energy FELs.

(U) Lethality work will develop a firm, physics-based understanding of the mechanisms involved in the interaction between HEL beams and the targets they strike. The expected payoffs from these efforts are databases accepted by the HEL community and validated models that are available to systems designers. Specific objectives are (1) developing and validating physics-based models, and (2) understanding and being able to apply the differences between continous wave lasers and pulsed lasers.

(U) Modeling and simulation efforts will continue to be increased with the goal of providing a fully realistic model of end-to-end system performance, from birth of photons in the laser to their death at the target, thereby improving the design of HEL systems and reducing the need for expensive field testing. Specific objectives include improving the HEL community's ability to simulate and model (1) individual HEL components, (2) HEL subsystems, (3) end-to-end HEL performance, and (4) HEL technology utility.

(U) It is expected that some of the projects begun in FY 2002 will continue in FY 2003. Continuation of a project will be contingent on the project's success in FY 2002 and on its relevance to the goals of the investment strategy.

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(U) B. Program Change Summary	FY 2001	FY 2002	FY 2003	Total Cost
Previous President's Budget Submission	0.000	0.000	0.945	Continuing
Delta	29.767	36.005	0.000	Continuing
FY 2002 Amended President's Budget Submission	29.767	36.005	0.945	Continuing
Appropriated Value	30.000	36.005	0.000	Continuing
Adjustments to Appropriated Value				
a. Congressionally Directed Undistributed Reduction	0.000	-0.774	0.000	Continuing
b. Rescission/Below-threshold Reprogramming, Inflation Adjustment	-0.277	0.000	0.000	Continuing
c. Other	0.000	0.000	38.365	Continuing
Current FY 2003 Budget Submission	29.723	35.231	39.310	Continuing

Change Summary Explanation:

(U) **Funding**: PE 06020890D8Z was established to address the imbalance in enabling science and technology and large demonstration programs for high-energy laser technology. FY 2001 reductions reflect Section 8086 adjustments. FY 2003 increases reflect a continued commitment by DoD in HEL Science & Technology.

(U) **Schedule**:

(U) **Technical**:

(U) **C.** **Other Program Funding Summary Cost**:

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(U) D. Acquisition Strategy:

(U) E. Schedule Profile: