PE NUMBER: 0602890F
PE TITLE: High Energy Laser Research

Exhibit R-2, RDT&E Budget Item Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602890F High Energy Laser Research

	Cost ($ in Millions)	FY 2004 Actual	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	Cost to Complete	Total
	Total Program Element (PE) Cost	40.458	50.229	45.678	49.598	49.986	54.179	55.439	56.383	Continuing	TBD
5096	High Energy Laser Research	40.458	50.229	45.678	49.598	49.986	54.179	55.439	56.383	Continuing	TBD

Note: In FY 2004, this program was transferred to the Air Force by the Office of the Secretary of Defense. The Air Force continues the tri-Service operation of the program under the High Energy Laser Joint Technology Office.

(U) A. Mission Description and Budget Item Justification

This program funds Department of Defense (DoD) high energy laser (HEL) applied research through the HEL Joint Technology Office. HEL weapon systems have many potential advantages, including speed-of-light velocity, high precision, significant magazine depth, low-cost per kill, and reduced logistics requirements. As a result, HELs have the potential to perform a wide variety of military missions including 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. This program is part of an overall DoD HEL Science and Technology program. In general, efforts funded under this program are chosen for their potential to have major impact on multiple HEL systems and on multiple Service missions while complementing Service/Agency programs that are directed at more specific Service needs. A broad range of technologies are addressed in key areas such as chemical lasers, solid-state lasers, beam control, optics, propagation, and free electron lasers. Note: In FY 2005, Congress added $2.4 million for the Joint High Power Solid State Laser program, $1.0 million for High Energy Laser Research, and $2.0 million for Manufacturing Technology Development Solid State of Advanced Components for High Solid State Laser.

This program is in Budget Activity 2, Applied Research, since it develops and determines the technical feasibility and military utility of evolutionary and revolutionary technologies.

(U) B. Program Change Summary ($ in Millions)

		FY 2004	FY 2005	FY 2006	FY 2007
(U)	Previous President's Budget	41.498	45.333	48.316	51.699
(U)	Current PBR/President's Budget	40.458	50.229	45.678	49.598
(U)	Total Adjustments	-1.040	4.896		
(U)	Congressional Program Reductions		-0.058		
	Congressional Rescissions		-0.446		
	Congressional Increases		5.400		
	Reprogrammings				
	SBIR/STTR Transfer	-1.040			

(U) Significant Program Changes:

In FY 2004, this program was transferred to the Air Force by the Office of the Secretary of Defense. The Air Force continues the tri-Service operation of the program under the HEL JTO.

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C. Performance Metrics
Under Development.

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DATE: February 2005

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PE NUMBER AND TITLE: 0602890F High Energy Laser Research

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Cost ($ in Millions)	FY 2004 Actual	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	Cost to Complete	Total
5096 High Energy Laser Research	40.458	50.229	45.678	49.598	49.986	54.179	55.439	56.383	Continuing	TBD
Quantity of RDT&E Articles	0	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

This program funds Department of Defense (DoD) high energy laser (HEL) applied research through the HEL Joint Technology Office. HEL weapon systems have many potential advantages, including speed-of-light velocity, high precision, significant magazine depth, low-cost per kill, and reduced logistics requirements. As a result, HELs have the potential to perform a wide variety of military missions including 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. This program is part of an overall DoD HEL Science and Technology program. In general, efforts funded under this program are chosen for their potential to have major impact on multiple HEL systems and on multiple Service missions while complementing Service/Agency programs that are directed at more specific Service needs. A broad range of technologies are addressed in key areas such as chemical lasers, solid-state lasers, beam control, optics, propagation, and free electron lasers. Note: In FY 2005, Congress added $2.4 million for the Joint High Power Solid State Laser program, $1.0 million for High Energy Laser Research, and $2.0 million for Manufacturing Technology Development Solid State of Advanced Components for High Solid State Laser.

This program is in Budget Activity 2, Applied Research, since it develops and determines the technical feasibility and military utility of evolutionary and revolutionary technologies.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2004	FY 2005	FY 2006	FY 2007
(U) MAJOR THRUST/CONGRESSIONAL ADD: Explore solid state lasers that have potential for the quickest impact in future HEL weapons because of their inherent small size and the fact that they require only electrical energy in order to run, thereby greatly simplifying systems engineering and supportability.	6.174	8.871	6.333	6.899

(U) In FY 2004: Conducted applied research to develop component technologies. This included thermal management, diode pump sources, gain media, and advanced configurations such as optical fibers. Developed thermal management with improved efficiency, and improved size and weight characteristics including heat capacitor technology. Developed diode pump sources with improved efficiency, lifetime, and brightness. Developed improved materials such as ceramics, which may provide improved optical-mechanical performance and controlled dopant profiles. Developed optical fiber technology including power scaling of single fibers, and fibers capable of coherent combination under various beam combination technologies.

(U) In FY 2005: Develop component technologies such as laser gain media with improved opto-thermal-mechanical properties. Develop thermal management techniques leading to reduced optical distortion, modular and scalable architectures for power scaling including beam combining, and optical ceramic materials. For ceramics, enhance manufacturing processes for laser applications, fully characterize materials, and set the stage for performance comparison to single crystal material. Develop

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and demonstrate more efficient and higher brightness diode arrays that can pump fiber lasers. Develop and demonstrate fiber laser beam combining through spectral and tiled aperture approaches. Develop and demonstrate a heat exchanger building block for phase change thermal management/storage systems. Conduct Service and Agency proposal call for FY 2005 and fund first year of selected efforts.

(U) In FY 2006: Conduct research to enable power scaling with reduced optical distortion, improved efficiency, and improved size and weight characteristics. Develop technology that will lead to improved fieldability, serviceability, and ruggedness. Develop scalable architectures for laser power scaling including technologies for beam combining. Examine architecture improvements, such as elimination of free-space optics in fiber systems. Conduct an industry proposal call for FY 2006, fund first year of selected efforts, and fund second year of FY 2005 Service and Agency efforts.

(U) In FY 2007: Continue maturing technologies that will provide system level performance commensurate with fieldable devices. Provide power scaling with good beam quality and suitable size and weight. Develop technology that will lead to improved fieldability, serviceability, and ruggedness. Explore power scaling technology that will lead to a broader application space. Develop new power-scalable architectures including technologies for beam combining. Continue to fund the contract efforts started in FY 2006, conduct Service and Agency proposal call for FY 2007, and fund first year of selected efforts.

(U)

(U) MAJOR THRUST: Explore free electron lasers (FEL) that have potential in future high energy laser (HEL) weapons because they require only electrical energy in order to run and can be designed to operate at the best wavelength for a specific application within a large range of wavelengths.	5.422	8.259	8.643	9.425

(U) In FY 2004: Developed enabling technologies for scaling free electron lasers to weapon-class power levels. Achieved 10 kilowatts from the laboratory demonstrator. Developed a photocathode model as a tool to design advanced robust long-life photocathodes. Designed and began fabrication of a high average current radio frequency cavity. Conducted a study to determine if new optical coating technologies produce coatings suitable for high-average-power FEL.

(U) In FY 2005: Develop FEL system components for power scaling. The 10 kilowatt laboratory demonstrator will be used as a test bed. Develop a separate photocathode test bed and refine photocathode models as a tool to design advanced robust, long-life photocathodes. Fabricate a high average current radio frequency cavity and study beam breakup mitigation technology. Perform laboratory tests to determine the suitability of high power optical components. Determine if currently planned technology for power scaling of the optical cavity will be satisfactory; explore alternatives as necessary. Conduct Service and Agency proposal call for FY 2005 and fund first year of selected efforts.

(U) In FY 2006: Conduct research in power scaling for powers in the 100 kilowatt class. Design high-average-current photocathode and injector capability, suitable beam-breakup thresholds, and power

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	scaling capability of the optical resonator. Continue component testing with the 10 kilowatt laboratory demonstrator to define a development path for scaling to a 100 kilowatt class field test demonstrator and eventual megawatt class free electron laser (FEL). Conduct an industry proposal call for FY 2006, fund first year of selected efforts, and fund second year of FY 2005 Service and Agency efforts.				
(U)	In FY 2007: Conduct system-level technology development and trade studies to facilitate scaling of FELs to weapon class power levels and shipboard integration. As appropriate, augment the existing 10 kilowatt laboratory testbed or build new testbeds with components showing traceability to larger systems, including radio frequency power systems, and optical and electron beam lines. Continue to investigate the development path for scaling toward 100 kilowatt field test demonstrator and eventual megawatt class FEL. Continue to fund the contract efforts started in FY 2006, conduct Service and Agency proposal call for FY 2007, and fund first year of selected efforts.				
(U)					
(U)	MAJOR THRUST/CONGRESSIONAL ADD: Develop advanced solid state laser technologies that are applicable to future high energy laser (HEL) weapon laser devices.	11.348	17.153	14.015	15.092
(U)	In FY 2004: Developed enabling solid state laser technologies through applied research necessary for the demonstration of solid state lasers at initial weapon-grade power levels. Under the Joint High Power Solid State Laser (JHPSSL) program, pursued development of solid state laser technologies supporting the demonstration of 25 kilowatts.				
(U)	In FY 2005: Demonstrate components for power scaling technology in concert with the 25 kilowatt JHPSSL. Develop hardware that can be used for quantitative characterization of the 25 kilowatt JHPSSL lasers. Develop enabling technologies that will support improved performance at 25 kilowatt and are traceable to 100 kilowatt.				
(U)	In FY 2006: Mature enabling technologies through applied research necessary for the demonstration of solid state lasers at initial weapon-grade power levels. Support technology development for the JHPSSL system in the 100 kilowatt program phase.				
(U)	In FY 2007: Continue to support the JHPSSL program design and demonstration of 100 kilowatts devices. Examine the potential for new technologies, such as dopant-tailored ceramics to impact this program.				
(U)					
(U)	MAJOR THRUST: Develop beam-control technologies that are directly applicable to surface, air, and space mission areas. 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. Develop atmospheric characterization technologies and techniques aimed at making precise absorption measurements in interesting atmospheric windows, measuring and assimilating information on turbulence at locations	10.481	8.182	8.562	9.329

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relevant to tactical high energy laser (HEL)systems, and developing and testing real-time characterization tools to assist the HEL operator.

(U) In FY 2004: Developed beam control technology to improve HEL system performance. Developed technology options for use on platforms such as tactical aircraft and ground vehicles. Developed technology to fabricate conformal HEL windows for tactical air vehicles. Developed wavefront sensors that are insensitive to high scintillation environments and prepared to benchmark performance in a simulated high scintillation environment. Established a government optical metrology capability to precisely measure adsorption and reflectivity of optical coatings. Developed methods for discrimination, pointing, and tracking in high clutter using three-dimensional imaging. Continued to characterize atmospheric limitations in low-altitude tactical scenarios in order to increase the lethal range.

(U) In FY 2005: Develop architecture and component technology that can be used to support integrated beam-control technology demonstrations. Address multiple architecture approaches, such as passive and active wavefront control, and target-in-the loop as well as wavefront-reconstruction based techniques. Explore next-generation component technology for phase control such as micro-electrical-mechanical and high power, high speed spatial light modulators. Explore improvement of optical coatings technology. Continue technology development for conformal windows and improved wavefront sensors for high scintillation environments. Continue atmospheric characterization and propagation studies for low-altitude tactical scenarios in order to increase the lethal range. Conduct Service and Agency proposal call for FY 2005 and fund first year of selected efforts.

(U) In FY 2006: Develop technology to support high performance beam control systems and integrated demonstrations. Explore advanced components and control techniques for difficult environments such as those found in high speed flight, high turbulence, and extended range. Advanced techniques include conformal and tiled apertures, and fiber-based technologies with improved isolation from platform disturbance. Develop component technology including durable optical coatings. Provide critical technology options for use in tactical scenarios on platforms such as aircraft, ground vehicles, and ships. Continue the study of atmospheric limitations in low-altitude tactical scenarios such as turbulence, thermal blooming, and with platform disturbances. Begin to plan an outdoor thermal blooming experiment. Conduct an industry proposal call for FY 2006, fund first year of selected efforts, and fund second year of FY 2005 Service and Agency efforts.

(U) In FY 2007: Mature existing and develop new technologies that support integrated beam control demonstrations. Continue technology development to support next-generation control technologies, such as all-solid fiber laser systems with conformal apertures and active control for boundary-layer mitigation. Provide technology options for laser use on multiple platforms (aircraft, ground vehicles, and ships). Continue study of atmospheric compensation technology. Continue to fund the contract efforts started in

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	FY 2006, conduct Service and Agency proposal call for FY 2007, and fund first year of selected efforts.				
(U)					
(U)	MAJOR THRUST: Develop chemical laser technologies that provide higher performance and better supportability. Results of these activities will result in chemical lasers that are lighter and more affordable. Emphasis in this area is being reduced based on the relative maturity of chemical lasers.	2.120	4.261	4.459	4.859
(U)	In FY 2004: Developed closed-cycle and recyclable chemical lasers, especially chemical oxygen iodine lasers appropriate for tactical applications. Emphasized technologies for improved battlefield operation and logistics. Developed chemical generators that are capable of operating in a gravity-free environment and conduct proof-of-concept testing of these devices.				
(U)	In FY 2005: Continue to develop and demonstrate closed-cycle chemical lasers, especially chemical oxygen iodine lasers. Continue to develop chemical laser generators that are capable of operating in a gravity free environment and conduct proof-of-concept testing of these devices. Evaluate advanced chemical or electrochemical cycles that promote improved recycling and use less hazardous materials. Conduct Service and Agency proposal call for FY 2005 and fund first year of selected efforts.				
(U)	In FY 2006: Continue to develop and demonstrate closed-cycle chemical lasers, especially chemical oxygen iodine laser-derived devices. Conduct technology development/experiments to allow selection of the most promising chemical generators and chemical regeneration techniques that can be scaled for tactical weapon applications. Conduct an industry proposal call for FY 2006, fund first year of selected efforts, and fund second year of FY 2005 Service and Agency efforts.				
(U)	In FY 2007: Continue to develop and demonstrate closed-cycle chemical lasers, especially chemical oxygen iodine laser-derived devices. Conduct technology development/experiments to allow selection of the most promising chemical laser generators and chemical regeneration techniques that can be scaled for tactical weapon system applications. Continue to fund the contract efforts started in FY 2006, conduct Service and Agency proposal call for FY 2007, and fund first year of selected efforts.				
(U)					
(U)	MAJOR THRUST: Develop lethality technologies that concentrate on providing a strong scientifically-based understanding of laser kill mechanisms to allow the design of future high energy laser (HEL) systems with the maximum kill probability for the minimum system size and cost.	4.142	3.503	3.666	3.994
(U)	In FY 2004: Developed a physics-based understanding of the mechanisms involved in the interaction between HEL beams and the targets. Developed databases that will be accepted by the HEL community and validated models that will be available to laser-weapon systems designers. Developed a subset of target folders for tactical laser weapons like the Advanced Tactical Laser and Mobile Tactical High Energy Laser.				
(U)	In FY 2005: Begin to explore feasibility of developing a predictive, physics-based model for target				

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lethality that would reduce the need for detailed lethality testing with the large number of known targets. Continue to develop databases that will be accepted by the HEL community and validated models that will be available to systems designers. Develop a subset of target folders for future tactical laser weapons. Conduct Service and Agency proposal call for FY 2005 and fund first year of selected efforts.

(U) In FY 2006: Continue work to establish a predictive, physics-based methodology for prediction of target lethality based on previously gained understanding of the mechanisms of interaction between laser beams and targets. Continue to develop databases that will be accepted by the high energy laser (HEL) community and validated models that will be available to systems designers. Conduct an industry proposal call for FY 2006, fund first year of selected efforts, and fund second year of FY 2005 Service and Agency efforts.

(U) In FY 2007: Continue to develop lethality information that will be accepted by the HEL community and validated models that will be available to systems designers. Continue to fund the contract efforts started in FY 2006, conduct Service and Agency proposal call for FY 2007, and fund first year of selected efforts.

(U)

(U)	MAJOR THRUST: Develop a fully realistic model of end-to-end HEL system performance, from the generation of photons in the laser to their impact on the target, thereby improving the design of HEL systems and reducing the need for expensive field testing.	0.771	0.000	0.000	0.000

(U) In FY 2004: Assessed available models and begin to develop the infrastructure for integrating existing and emerging high-fidelity component models into an end-to-end engagement model, thereby improving the design of HEL systems and reducing the need for expensive field testing. Developed a widely accepted engagement model for non-expert users capable of supporting many HEL systems, targets, and scenarios. The model included platform constraints, provided parametrically represented probability of kill for various target surfaces, and allowed for constrained sensitivity analyses.

(U) In FY 2005: Develop the infrastructure for integrating existing and emerging high-fidelity component models into an end-to-end engagement model, thereby improving the design of HEL systems and reducing the need for expensive field testing. Continue to develop a widely accepted engagement model for non-expert users capable of supporting many HEL systems, targets, and scenarios. The model will include platform constraints, provide parametrically represented probability of kill for various target surfaces, and allow for constrained sensitivity analyses. Conduct Service and Agency proposal call for FY 2005 and fund first year of selected efforts.

(U) In FY 2006: Begin validation of infrastructure for integrating existing and emerging high-fidelity component models into an end-to-end engagement model, thereby improving the design of HEL systems and reducing the need for expensive field testing. Begin to validate engagement model using Service

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specific scenarios. Conduct an industry proposal call for FY 2006, fund first year of selected efforts, and fund second year of FY 2005 Service and Agency efforts.

(U) In FY 2007: Continue the validation process of infrastructure for integrating existing and emerging high-fidelity component models into an end-to-end engagement model, thereby improving the design of HEL systems and reducing the need for expensive field testing. Begin to validate engagement model using Service specific scenarios. Continue to fund the contract efforts started in FY 2006, conduct Service and Agency proposal call for FY 2007, and fund first year of selected efforts.

(U) Total Cost	40.458	50.229	45.678	49.598

(U) C. Other Program Funding Summary ($ in Millions)

	FY 2004 Actual	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	Cost to Complete	Total Cost
(U) PE 0602500F, Multi-Disciplinary Space Technology.										
(U) PE 0601108F, High Energy Laser Research Initiatives.										
(U) PE 0603444F, Maui Space Surveillance System.										
(U) PE 0603500F, Multi-Disciplinary Advanced Development Space Technology.										
(U) PE 0603605F, Advanced Weapons Technology.										
(U) PE 0603924F, High Energy Laser Advanced Technology Program.										
(U) PE 0603883C, Ballistic Missile Defense Boost Phase Segment.										
(U) PE 0602605F, Directed Energy Technology.										
(U) PE 0602307A, Advanced										

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(U) C. Other Program Funding Summary ($ in Millions)

(U) Weapons Technology. PE 0602114N, Power Projection Applied Research. This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.