PE NUMBER: 0602203F
PE TITLE: Aerospace Propulsion

Exhibit R-2, RDT&E Budget Item Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied 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
	Total Program Element (PE) Cost	126.295	132.918	107.523	115.360	111.064	116.822	118.426	119.872	Continuing	TBD
3012	Advanced Propulsion Technology	16.681	13.094	18.876	23.974	22.228	22.654	23.038	23.392	Continuing	TBD
3048	Fuels and Lubrication	17.540	16.098	14.371	16.255	12.842	13.553	13.674	13.774	Continuing	TBD
3066	Turbine Engine Technology	31.341	34.345	32.095	31.600	33.881	35.948	36.398	36.802	Continuing	TBD
3145	Aerospace Power Technology	36.155	44.152	30.134	29.025	31.144	33.201	33.724	34.203	Continuing	TBD
4847	Rocket Propulsion Technology	24.578	25.229	12.047	14.506	10.969	11.466	11.592	11.701	Continuing	TBD

(U) A. Mission Description and Budget Item Justification

This program develops propulsion and power technologies to achieve enabling and revolutionary aerospace technology capabilities. The program has five projects, each focusing on a technology area critical to the Air Force. The Advanced Propulsion Technology develops high-speed airbreathing propulsion engines to include combined cycle, ramjet, and hypersonic scramjet technologies to enable revolutionary propulsion capability for the Air Force. The Fuels and Lubrication project develops new fuels, lubricants, and combustion concepts and technologies for new and existing engines and directly supports the Integrated High Performance Turbine Engine Technology (IHPTET) and the Versatile Affordable Advanced Turbine Engine (VAATE) programs. The Turbine Engine Technology project develops enabling capabilities to enhance performance and affordability of existing weapon systems to include efforts that are part of the IHPTET and VAATE programs. The Aerospace Power project develops efficient energy conversion/storage, power generation/power conditioning/distribution, and thermal management techniques for ground, air, and space military applications. Finally, the Rocket Propulsion Technology project pursues advances in rocket technologies for space access, space maneuver, and tactical and strategic missiles to include efforts that are part of the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) and Technology for the Sustainment Systems (TSSS) programs. Note: In FY 2005, Congress added $1.0 million for Information Assurance Initiative; $1.0 million for Intense, Ultrafast Laser Microfabrication and Diagnostics; $1.0 million for Wavelength Agile Spectral Harmonic Oxygen Sensor; $1.4 million for Hybrid Bearings; $1.0 million for Versatile Affordable Advanced Turbine Engine-Titanium Matrix Composites; $1.9 million for Center for Flow Physics and Control; $1.5 million for Cell-Level Battery Controller; $1.0 million for Lightweight Photovoltaic for Portable Power and Hydrogen Generation; $3.1 million for Hypersonics Vehicle Electric Power Systems; $6.5 million for High Powered Electrical Aircraft Capabilities; $1.9 million for Center for Security of Large-Scale Systems; $1.5 million for Remote-Base Power Demonstration; $2.8 million for Integrated Cooling and Power System with Magnetic Bearing Turbogenerator; $1.3 million for Advanced Cooling Technology for High Flux Military Diode Laser Arrays; $4.0 million for Advanced Vehicle and Propulsion Center; $6.8 million for Jet and Rocket Engine Test Site; $1.0 million for Aerospace Laboratory Equipment Upgrade; $1.0 million for Advanced Aerospace Vehicle Cooling Technologies; $0.75 million for High Regression Rate Hybrid Rocket Fuels; and $1.0 million for Engineering Research Laboratory Equipment Upgrade. 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.

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

		FY 2004	FY 2005	FY 2006	FY 2007
(U)	Previous President's Budget	126.988	92.650	109.833	119.239
(U)	Current PBR/President's Budget	126.295	132.918	107.523	115.360
(U)	Total Adjustments	-0.693	40.268		
(U)	Congressional Program Reductions				
	Congressional Rescissions		-1.182		
	Congressional Increases		41.450		
	Reprogrammings				
	SBIR/STTR Transfer	-0.693			
(U)	Significant Program Changes:				

Not Applicable.

C. Performance Metrics

(U) Under Development.

Exhibit R-2a, RDT&E Project Justification

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PROJECT NUMBER AND TITLE: 3012 Advanced Propulsion Technology

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
3012 Advanced Propulsion Technology	16.681	13.094	18.876	23.974	22.228	22.654	23.038	23.392	Continuing	TBD
Quantity of RDT&E Articles	0	0	0	0	0	0	0	0		

Note: In FY 2005, funding level was reduced as Air Force efforts shifted from variable-geometry demonstrators to Advanced Technology Development (6.3) fixed-geometry demonstrators. In FY 2006, 2007, and 2008 funding was increased to accelerate efforts to develop technologies to support an Air Force scramjet effort.

(U) A. Mission Description and Budget Item Justification

This project develops combined/advanced cycle airbreathing high-speed (up to Mach 4) and hypersonic (Mach 4 to 8+) propulsion technologies to provide revolutionary propulsion options for the Air Force. These new engine technologies will enable future high-speed/hypersonic weapons and aircraft concepts. The primary focus is on hydrocarbon-fueled engines capable of operating over a broad range of flight Mach numbers. Technologies developed under this program enable capabilities of interest to both Department of Defense and NASA. Efforts include modeling, simulations, and proof of concept demonstrations of critical components; advanced component development; and ground-based demonstrations.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2004	FY 2005	FY 2006	FY 2007
(U) MAJOR THRUST: Develop advanced fuel-cooled scramjet engine technologies to support flight demonstration and enable the broad application of hypersonics to meet future warfighter needs. Note: In FY 2005, start of ground demonstrations was delayed until FY 2006 due to shift in type of demonstrator.	16.113	7.441	7.813	11.685

(U) In FY 2004: Developed flight weight engine components including flight weight fuel control valves, fuel pumps, and engine controllers. Initiated detailed analysis for mating scramjet flight engines with demonstrator vehicles. Performed trajectory optimization for flight test. Evaluated options for scramjet start, including gas generator/heat exchanger system, barbotage fuel injection, plasma ignition, and silane injection with a mechanical throat or air throttle. Verified operation of engine control techniques, based on rapid shock train identification/characterization coupled with fuel control logic, to ensure stable scramjet operation. Initiated fabrication of a flight weight ground test engine with a fuel cooled structure incorporating a variable geometry inlet. Note: In FY 2004, several of these activities were moved from PE 0602500F, Project 5027, to consolidate all 6.2 scramjet non-space unique demonstration efforts.

(U) In FY 2005: Continue flight weight engine components development including flight weight fuel control valves, fuel pumps, and engine controllers. Complete detailed analysis mating of scramjet flight engines to demonstrator vehicles. Continue performing trajectory optimization for flight test. Continue evaluating options for scramjet start, including gas generator/heat exchanger system, barbotage fuel injection, plasma ignition, and silane injection with a mechanical throat or air throttle. Continue verification of engine control techniques, based on rapid shock train identification/characterization coupled with fuel control logic, to ensure stable scramjet operation. Complete fabrication of a flight weight, fuel-cooled ground test engine with a variable geometry inlet.

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(U)	In FY 2006: Continue development and demonstration of flight weight engine components and a control system with closed loop controller. Continue performing trajectory optimization for flight test. Continue evaluating options for scramjet start, including gas generator/heat exchanger system, barbotage fuel injection, plasma ignition, and silane injection with a mechanical throat or air throttle. Continue verification of operation of engine control techniques, based on rapid shock train identification/ characterization coupled with fuel control logic, to ensure stable scramjet operation. Design, fabricate, and initiate ground test of a flight weight, fixed geometry inlet scramjet engine with improved operability to reduce flight test risk.				
(U)	In FY 2007: Continue development and demonstration of flight weight engine components and a control system with closed loop controller. Continue performing trajectory optimization for flight test. Continue evaluating options for scramjet start, including gas generator/heat exchanger system, barbotage fuel injection, plasma ignition, and silane injection with a mechanical throat or air throttle. Continue verification of operation of engine control techniques, based on rapid shock train identification/ characterization coupled with fuel control logic, to ensure stable scramjet operation. Complete ground test of a flight weight, fixed geometry inlet scramjet engine with improved operability to reduce flight test risk.				
(U)					
(U)	MAJOR THRUST: Conduct assessments, system design trades, and simulations to integrate combined cycle engines (CCEs) and advanced cycle airbreathing hypersonic propulsion technologies into future missiles and into manned and unmanned air and space vehicle concepts. CCEs require the development and demonstration of components to integrate scramjets with high speed turbines and/or rocket engines for efficient propulsion over a broad range of Mach numbers.	0.568	0.256	1.095	2.144
(U)	In FY 2004: Initiated system trade studies to determine military payoff and establish component technology goals. Initiated defining component and engine performance objectives to enable development of affordable hypersonic flight demonstrators jointly with NASA and the Defense Advanced Research Projects Agency (DARPA). Note: In FY 2004, these non-space unique activities were moved from PE 0602500F, Project 5027.				
(U)	In FY 2005: Continue system trade studies to determine military payoff and establish component technology goals. Continue defining component and engine performance objectives to enable development of affordable hypersonic flight demonstrators jointly with NASA and DARPA.				
(U)	In FY 2006: Continue system trade studies to determine military payoff and establish component technology goals. Continue defining component and engine performance objectives to enable development of affordable hypersonic flight demonstrators jointly with NASA and DARPA. Initiate development of advanced components for turbine-based and rocket-based CCEs. Initial emphasis is on				

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advanced inlets for turbine-based CCEs capable of operating for Mach 0-8. Design sub-scale inlet test article.

(U) In FY 2007: Continue system trade studies to determine military payoff and establish component technology goals. Continue defining component and engine performance objectives to enable development of affordable hypersonic flight demonstrators jointly with NASA and DARPA. Continue development of advanced components for turbine-based and rocket-based CCEs. Fabricate and initiate test of advanced inlets for turbine-based CCEs capable of operating for Mach 0-Mach 8.

(U)

(U) MAJOR THRUST: Develop robust hydrocarbon fueled scramjet engine components and technologies to improve performance, operability, durability, and scalability for future missiles and for aerospace vehicles. Note: In FY 2005, these activities were moved from PE 0602500F, Project 5027 to consolidate all 6.2 scramjet development efforts.	0.000	4.406	9.968	10.145

(U) In FY 2004: Not Applicable.

(U) In FY 2005: Continue development of advanced engine components to improve scramjet operating margin and to establish scramjet scaling laws for reusable applications. Develop techniques to decrease scramjet take-over from Mach 4.5 to Mach 3.5 to provide robust options for CCEs. Support development of low internal drag flame stabilization devices and flight test engine components.

(U) In FY 2006: Continue development of advanced engine components to improve scramjet operating margin and to establish scramjet scaling laws for reusable applications. Continue development of variable geometry techniques to decrease scramjet take-over from Mach 4.5 to Mach 3.5 to provide robust options for CCEs. Fabricate and initiate test of scramjet combustors sized for reusable applications with improved structural efficiency. Support development of low internal drag flame stabilization devices and flight test engine components.

(U) In FY 2007: Continue development of advanced engine components to improve scramjet operating margin and to establish scramjet scaling laws for reusable applications. Continue development of variable geometry techniques to decrease scramjet take-over from Mach 4.5 to Mach 3.5 to provide robust options for CCEs. Complete test of scramjet combustors sized for reusable applications with improved structural efficiency. Initiate development of improved durability engine concepts. Continue development of low internal drag flame stabilization devices and flight test engine components.

(U)

(U) CONGRESSIONAL ADD: Information Assurance Initiative.	0.000	0.991	0.000	0.000

(U) In FY 2004: Not Applicable.

(U) In FY 2005: Support the Air Force Research Laboratory-Propulsion Directorate Information Assurance Initiative by facilitating information technology infrastructure security upgrades in compliance with

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Congressional mandates.

(U) In FY 2006: Not Applicable.

(U) In FY 2007: Not Applicable.

(U) Total Cost	16.681	13.094	18.876	23.974

(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) Related Activities:										
(U) PE 0601102F, Defense Research Sciences.										
(U) PE 0602201F, Aerospace Flight Dynamics.										
(U) PE 0602500F, Multi-Disciplinary Space Tech.										
(U) PE 0602602F, Conventional Munitions.										
(U) PE 0602702E, Tactical Technology.										
(U) PE 0603211F, Aerospace Structures.										
(U) PE 0603216F, Aerospace Propulsion and Power Technology.										
(U) PE 0603601F, Conventional Weapons Technology.										
(U) Program is reported to/coordinated by the Joint Army/Navy/NASA/Air Force (JANNAF) Executive Committee.										
(U) This project has been coordinated through the										

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

Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.

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PROJECT NUMBER AND TITLE: 3048 Fuels and Lubrication

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
3048	Fuels and Lubrication	17.540	16.098	14.371	16.255	12.842	13.553	13.674	13.774	Continuing	TBD
	Quantity of RDT&E Articles	0	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

This project develops improved fuels, lubricants, mechanical systems, and combustion concepts for advanced turbine engines, scramjets, pulse detonation, and combined cycle engines, and technology to increase turbine engine operational reliability, durability, mission flexibility, and performance while reducing weight, fuel consumption, and cost of ownership. Systems applications include missiles, aircraft, sustained high-speed vehicles, and responsive space launch. Analytical and experimental areas of emphasis include fuels and fuels logistics, lubricants, bearings, electromagnetic rotor, oil-less engine technology, optical diagnostics, fundamental combustion, and detonations. Fuels and lubricants for these engines must be thermally stable, cost-effective, and operate over a broad range of conditions. Advanced combustion concepts must be cost-effective, durable, and reduce pollutant emissions.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2004	FY 2005	FY 2006	FY 2007
(U) MAJOR THRUST: Develop low-cost additive and fuel system approaches to improve fuel properties and to expand the flight envelope for manned and unmanned aircraft.	1.994	1.599	1.806	2.042

(U) In FY 2004: Developed additive packages to enable JP-8 to achieve jet propulsion at thermally stable low temperatures (high altitude). Developed approaches to increase JP-8 temperature capability to 900 degrees Fahrenheit, including thermal stability additives, fuel deoxygenation, and improved coatings. Enhanced existing fuel modeling and simulation capabilities by incorporation of more realistic additive performance models and detailed fuel chemistry.

(U) In FY 2005: Complete additive package optimization and test protocols to enable JP-8 to achieve jet propulsion at thermally stable low temperatures. Conduct lab-scale evaluation of approaches to increase JP-8 temperature capability to 900 degrees Fahrenheit, including thermal stability additives, fuel deoxygenation, and improved materials and coatings. Continue enhancing existing fuel modeling and simulation capabilities by incorporating more realistic additive performance models. Develop engine thermal management models.

(U) In FY 2006: Continue conducting lab-scale evaluation of approaches to increase JP-8 temperature capability to 900 degrees Fahrenheit including thermal stability additives, fuel deoxygenation, advanced alternative energy fuels, and improved materials and coatings. Complete initial development of engine thermal management models, aiming toward system-level models of advanced aircraft. Initiate development of laboratory-scale combustion tests for evaluating combustion performance of fuels and additives at low fuel and air temperatures.

(U) In FY 2007: Continue conducting lab-scale evaluation of approaches to increase JP-8 temperature capability to 900 degrees Fahrenheit including thermal stability additives, fuel deoxygenation, advanced alternative energy fuels, and improved materials and coatings. Initiate effort to validate component

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	performance models on aircraft thermal management simulator. Continue to develop approaches to assess and improve additive combustion behavior at low fuel and air temperatures. Test fuel candidates in bench scale rigs simulating advanced high Mach propulsion systems.				
(U)					
(U)	MAJOR THRUST: Develop advanced additive approaches to reduce engine emissions and signature (including nano-scale additives), as well as, advanced emission diagnostic test protocols. Note: In FY 2004, the emissions and signature reduction activities became a separate effort in this Project.	1.081	0.991	1.119	1.266
(U)	In FY 2004: Developed emission reduction additives. Verified additives performance in laboratory-scale combustion tests. Initiated development of improved diagnostics for sub-micron scale particulate emissions from combustors.				
(U)	In FY 2005: Continue assessing additional additives performance in laboratory scale combustion tests. Complete development and application of advanced diagnostics for sub-micron particulate emissions.				
(U)	In FY 2006: Continue assessing novel fuel additives including nano-technologies and fuels derived from alternative energy resources to reduce emissions in laboratory scale combustion rigs. Develop higher-pressure laboratory-scale combustion tests and diagnostics for sub-micron particulate investigations.				
(U)	In FY 2007: Complete assessing novel fuel additives including nano-technologies and fuels derived from alternative energy resources to reduce emissions in laboratory scale combustion rigs. Initiate higher-pressure measurements of additive and fuel effects on sub-micron particulate generation during combustion.				
(U)					
(U)	MAJOR THRUST: Study and evaluate low-cost approaches to reduce fuel logistics footprint to simplify logistics and reduce cost (including field and on-board additive injections and improvements to existing fuel additive packages), as well as study fuel logistics vulnerabilities and develop detection and mitigation technologies.	1.118	0.991	1.119	1.266
(U)	In FY 2004: Developed improvements to existing fuel additive packages to simplify logistics and reduce cost. Conducted initial assessment of the performance of fuels from alternative sources, including Fischer-Tropsch fuels. Initiated investigation of biological contamination in fuel supply chain. Tested candidate technologies for field-fuel quality diagnostics. Investigated the use of field-portable equipment to measure biological contamination in fuels.				
(U)	In FY 2005: Develop improvements to existing fuel additive packages to simplify logistics and reduce cost. Continue assessing performance of fuels from alternative sources, including Fischer-Tropsch fuels and bio-derived fuels. Further investigate biological contamination in fuels and the impact of fuel logistic supply chains. Develop field mitigation techniques for biological fuel contamination. Continue development of new field fuel quality diagnostics for fuel properties and bio-contamination.				

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(U)	In FY 2006: Complete assessment of fuel additives optimization for logistics footprint reduction. Continue to investigate performance of Fischer-Tropsch and other alternative fuels for aircraft and other field hardware. Complete investigation of supply chain biological contamination and the impact on fuel logistics. Initiate evaluation of nano-technology fuel sensors and biological mitigation techniques. Complete development of advanced field diagnostics techniques for fuel properties and bio-contamination.				
(U)	In FY 2007: Continue to investigate performance of Fischer-Tropsch and other alternative fuels for aircraft and other field hardware. Continue evaluation of advanced nano-technology fuel sensors, nano-technology fuel additives, and novel detection and mitigation technologies for biological growth.				
(U)					
(U)	MAJOR THRUST: Investigate hydrocarbon and other high energy density fuels for advanced and combined cycle engines for high-speed aerospace vehicles and low-cost boost applications.	0.508	0.496	0.560	0.633
(U)	In FY 2004: Completed preliminary development of fuel property and performance data for industry and Government use in selecting alternative hydrocarbon fuels for advanced propulsion. Investigated approaches to assess fuel thermal stability under high heat flux conditions relevant to advanced rockets and combined cycle engines.				
(U)	In FY 2005: Develop fuel property and performance database for industry and Government use in selecting alternative hydrocarbon fuels for boost applications. Test approaches to assess fuel thermal stability under high heat flux conditions relevant to advanced rockets and combined cycle engines.				
(U)	In FY 2006: Continue to assess advanced hydrocarbon propellant stability under high heat flux conditions for advanced rockets and combined cycle engines.				
(U)	In FY 2007: Continue to assess advanced hydrocarbon propellant stability under high heat flux conditions. Collect improved fuel property data for hydrocarbon propellant database.				
(U)					
(U)	MAJOR THRUST: Develop, test, and evaluate revolutionary combustor and propulsion concepts for gas turbine, pulsed detonation, and combined cycle engines for missiles, manned and unmanned systems, and reuseable access to space; perform payoff analyses and configuration trade studies for these systems; and evaluate the combustion and emissions characteristics of fuels and fuel additives.	3.490	3.454	3.899	4.411
(U)	In FY 2004: Evaluated advanced combustor concepts and the inter-turbine burner combustor at conditions that simulate turbine-wake and turbine-inlet interactions. Investigated the performance of a rudimentary combined cycle pulse detonation engine (PDE). Evaluated the technical issues associated with incorporating PDE propulsion technologies into gas turbine engines. Performed experiments to validate the high-speed performance of a pure PDE. Completed tests to evaluate promising fuel additives used to reduce particulates and emissions from gas turbine engines.				
(U)	In FY 2005: Evaluate the inter-turbine burner combustor at realistic operating conditions with rotating				

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turbine machinery. Evaluate and develop combined cycle PDE concepts. Address the operational issues associated with incorporating PDE propulsion technologies into gas turbine engines. Conduct experiments to extend the operability limits of pure PDE for application to high-speed missiles. Evaluate fundamental combustion issues associated with combustors fed by high-temperature fuel systems like those required for supersonic cruise aircraft.

(U) In FY 2006: Begin evaluating advanced combustion system performance at realistic operating conditions. Start investigating larger-scale inter-turbine burner concepts at relevant engine operating conditions to increase mission flexibility. Continue developing a PDE into turbine-based hybrid concept. Conduct experiments to validate chemical kinetics of practical fuels at high pressure and temperature. Perform modeling and simulation of advanced combustion systems to decrease design cycle time, optimize compact combustor, and augmentor designs, and to understand physical parameters controlling combustion processes. Evaluate and develop novel lightweight, high performance augmentor concepts.

(U) In FY 2007: Continue evaluating advanced combustion system performance at realistic operating conditions. Continue investigating inter-turbine burning concepts for large gas turbine engines. Continue integration of PDE into turbine-based hybrid concept. Evaluate and optimize advanced combustor, augmentor, and PDE concepts using modeling and simulation tools.

(U)

(U) MAJOR THRUST: Develop approaches to extend the life of endothermic fuels and fuel system components for sustained supersonic and reusable hypersonic cruise applications.	0.961	0.496	0.560	0.635

(U) In FY 2004: Developed approaches to improve fuel heat sink capability. Developed systems to minimize regenerative cooling heat loads absorbed by endothermic fuel systems. Developed means to improve fuel combustion performance, especially during cold start and cycle transition. Improved fuel system modeling and simulation tools to better simulate endothermic fuel behavior.

(U) In FY 2005: Evaluate, at a laboratory scale, approaches to improve fuel heat sink capability. Test systems to minimize regenerative cooling heat loads absorbed by endothermic fuel systems. Test means to improve fuel combustion performance, especially during cold start and cycle transition. Complete improving fuel system modeling and simulation tools to better simulate endothermic fuel behavior.

(U) In FY 2006: Continue evaluating, at a laboratory scale, approaches to improve fuel heat sink and provide thermal management capability for high speed systems. Evaluate surface/catalyst effects on coke reduction to improve fuel heat sink capability and increase fuel system life. Initiate assessment of unconventional approaches to increase fuel heat sink, such as steam reforming.

(U) In FY 2007: Continue development of improved surfaces/catalysts to mitigate coking and thus improve fuel heat sink capability. Continue assessment of unconventional approaches to increase fuel heat sink and minimize regenerative cooling heat loads, including low heat rejection structures.

(U)

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(U)	MAJOR THRUST: Develop and demonstrate optical, electromechanical, and laser diagnostic tools and sensors for application to revolutionary propulsion technologies.	0.890	0.622	0.702	0.794
(U)	In FY 2004: Investigated pollutant emission formation pathways through computational and experimental methods. Evaluated methods to reduce gaseous and particulate pollutant emission from legacy and future gas turbine engines. Investigated high intensity laser light interaction with matter for micromachining and diagnostic capabilities. Completed preliminary development and demonstration of sensors for the control of combustor performance and extension of component life.				
(U)	In FY 2005: Complete developing and testing sensors for the control of combustor performance and extension of component life. Develop diagnostic tools to evaluate the combustion issues related to engines burning high-temperature fuels. Initiate investigation of the interaction of high intensity laser light with matter for micromachining and diagnostic capabilities.				
(U)	In FY 2006: Begin applying advanced laser diagnostics for accurate measurements inside advanced gas turbine combustion systems that will improve design cycle time. Develop sensor technologies for use in intelligent gas turbine engine combustion systems for enhanced operability, increased durability and performance. Continue investigation of high intensity laser light with matter for micromachining and diagnostic capabilities.				
(U)	In FY 2007: Continue application of advanced diagnostics in a relevant gas turbine combustion system environment. Apply diagnostics to sensor development and validate sensors in relevant gas turbine engine system. Conduct experiments to obtain benchmark-quality data for improvement of combustion modeling and simulation tools.				
(U)					
(U)	MAJOR THRUST: Develop, test, and conduct qualification activities to provide the most reliable and affordable advanced turbine engine lubricants to the Air Force, DoD, and commercial users. Generate and maintain military specifications for aviation engine lubricants, as well as continued field support activities for aviation lubrication technologies and DoD operational units.	1.896	1.923	2.171	2.455
(U)	In FY 2004: Developed and tested advanced bearing and lubrication system concepts, components, and materials for improved engine performance, affordability, and engine health monitoring. Performed payoff analyses and configuration trade studies to define, focus, and evaluate research in lubricants and mechanical systems for man-rated, expendable, high-Mach, and unmanned air vehicle (UAV) turbine engines. Improved vapor lubricants for the expendable and small high Mach vehicles in support of a Navy demonstration, as well as follow on programs. Developed corrosion inhibition additives for improved storability of UAV engines. Transitioned some optimal ester lubricants to military and commercial turbine engines.				
(U)	In FY 2005: Expand development and test of advanced bearing and lubrication system concepts, components, and materials for improved engine performance, affordability, and engine health				

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monitoring. Initiate testing to focus and develop lubricants and mechanical systems for man-rated, expendable, and UAV turbine engines. Design test approaches for optimal ester lubricant to military and commercial turbine engines. Coordinate oil research and development activities between Government, engine manufacturers, and oil companies in support of the Joint Oil Program (JOP). Engage oil companies to deliver prototype lubricants and initiate bench top evaluation. Design test approaches for JOP lubricants for use in new fighter demonstration engines.

(U) In FY 2006: Continue development and testing of advanced bearing and lubrication system concepts, components, and materials for improved engine performance, affordability, and engine health monitoring. Continue testing to focus and develop lubricants and mechanical systems for man-rated, expendable, and UAV turbine engines. Design test approaches for enhanced high thermal stability (HTS) oils for new, legacy, and commercial turbine engines. Focus optimal ester lubricant development on high Mach/high temperature military and commercial turbine engines. Test prototype JOP lubricants with mechanical hardware in preparation of new fighter demonstration engines.

(U) In FY 2007: Begin technology insertion of advanced bearing and lubrication system concepts, components, and materials for improved engine performance, affordability, and engine health monitoring into demonstrator cores and engines. Continue testing to focus and develop lubricants and mechanical systems for man-rated, expendable, and UAV turbine engines. Continue optimal ester lubricant development for high Mach/high temperature military and commercial turbine engines. Coordinate and support demonstration of JOP lubricants in new fighter asset engines. Deliver military specifications and test methods for DoD lubricants to support new fighter engines.

(U)

(U)	MAJOR THRUST: Develop and test advanced bearing technology concepts for small, intermediate, and large-sized turbine engine applications.	2.675	2.156	2.435	2.753

(U) In FY 2004: Performed full-scale rig tests of electromagnetic rotor support and a power generation system for advanced, oil-less engines. Completed initial studies and tested airfoil shaft bearings for propulsion turbine engine application. Developed and tested affordable rotor support technology for small, intermediate, and large-sized turbine engine applications. Enhanced modeling and simulation capabilities to advance design, shorten development time, and reduce test requirements for mechanical and electromagnetic rotor support and power generation systems. Completed preliminary modeling rotordynamics of airfoil shaft bearing supported engine shafts. Conducted advanced rotor support and power generation studies and start tests for turbine and combined cycle engines. Developed the primary approach and roadmaps for the hybrid (metal/ceramic) bearing technology for the new fighter demonstrator engines. Supported industry in developing on-line engine mechanical systems diagnostics. Assisted in thermal analysis of mechanical systems for a NASA developed turbine engine.

(U) In FY 2005: Initiate airfoil shaft bearing tests to determine load capacity and rotor size limitations of this

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technology. Continue development and test of affordable rotor support technology for small-, intermediate-, and large-sized turbine engine applications, specifically ultra-high temperature lubrication concepts and composite bearing cages for supersonic missile engines. Enhance modeling and simulation activities to advance design, shorten development time, and reduce test requirements for mechanical and electromagnetic rotor support and power generation systems. Conduct modeling of airfoil shaft bearings and iterate results with test activity. Support industry development of hybrid (metal/ceramic) bearing designs for new fighter engines. Note: FY 2005 combined cycle engine rotor/power efforts were delayed until FY 2007 to accelerate the new fighter bearing efforts.

(U) In FY 2006: Continue conducting airfoil shaft bearing testing in large shaft diameter sizes to determine load capacity and rotor size limitations of this technology. Continue development and test of affordable rotor support technology for small-, intermediate-, and large-sized turbine engine applications. Continue enhancement of modeling and simulation activities to advance design, shorten development time, and reduce test requirements for mechanical and electromagnetic rotor support and power generation systems. Continue modeling airfoil shaft bearings for advanced engine rotor support and power generation. Begin full-scale tests of hybrid (metal/ceramic) bearing technology for the new fighter demonstrator engines with lubricant from the JOP. Initiate study of mechanical systems thermal management concepts for turbo accelerators in combined cycle engines.

(U) In FY 2007: Continue conducting airfoil shaft bearing tests in larger shaft diameter sizes to determine load capacity and rotor size limitations of this technology. Continue development and test of affordable rotor support technology for small-, intermediate-, and large-sized turbine engine applications. Continue enhancement of modeling and simulation activities to advance design, shorten development time, and reduce test requirements for mechanical and electromagnetic rotor support and power generation systems. Improve the modeling of airfoil shaft bearings and initiate evaluation of insertion opportunities for advanced engine rotor support and power generation. Continue transition/transfer of airfoil shaft bearing technology to bearing and engine companies. Demonstrate hybrid (metal/ceramic) bearing and JOP lubricants in the new fighter demonstrator engines. Initiate programs for hardware needed for optimum thermal protection designs for high mach/high temperature turbine engines and accelerators. Expand the previous studies of advanced rotor support and power generation for turbine and combined cycle engines.

(U)

(U)	CONGRESSIONAL ADD: Pulse Detonation Engine Development and SBIR Phase III including Laser Induced Thermal Acoustics Instrument Development.	2.927	0.000	0.000	0.000

(U) In FY 2004: Completed the design of key components to include the inlet, intake valve, fuel injector, initiator, controller, and thrust tube for an airbreathing PDE for use in subsonic and supersonic unmanned air vehicles. Performed design validation tests of the key components and developed engineering models

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	to guide the design. Advanced the design of a demonstration vehicle for eventual flight test of the PDE. Developed and evaluated a Laser Induced Thermal Acoustics instrument for characterization of combusting flows.				
(U)	In FY 2005: Not Applicable.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Intense, Ultrafast Laser Microfabrication and Diagnostics.	0.000	0.991	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Develop the technology base required to reduce the development, production, and maintenance costs of advanced weapon systems through the use of intense, ultrafast lasers.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Wavelength Agile Spectral Harmonic Oxygen Sensor.	0.000	0.991	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Develop a sensor using wavelength agile spectral harmonics to measure oxygen concentration in high-performance fuel tanks, allowing the verification and optimization of nitrogen inerting.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Hybrid Bearings. Note: Efforts expand upon activities in a FY 2004 Congressional Add in PE 0603112F, Project 3946.	0.000	1.388	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Accelerate the development of advanced hybrid bearing technology, which will provide 25 percent increase in thrust load and speed capability, increased reliability, and safety margin of aircraft turbine engines.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)	Total Cost	17.540	16.098	14.371	16.255

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(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) Related Activities:										
(U) PE 0601102F, Defense Research Sciences.										
(U) PE 0602805F, Dual Use Science and Technology.										
(U) PE 0603216F, Aerospace Propulsion and Power Technology.										
(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.										

(U) D. Acquisition Strategy

Not Applicable.

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PROJECT NUMBER AND TITLE: 3066 Turbine Engine Technology

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
3066	Turbine Engine Technology	31.341	34.345	32.095	31.600	33.881	35.948	36.398	36.802	Continuing	TBD
	Quantity of RDT&E Articles	0	0	0	0	0	0	0	0		

Note: In FY 2004, funding will be concentrated on completing the turbofan/turbojet gas generator technology efforts under the Integrated High Performance Turbine Engine Technology (IHPTET) program as it comes to completion in FY 2005. In FY 2005, the funding will be distributed to the broader turbine technology efforts as the Versatile Affordable Advanced Turbine Engine (VAATE) program ramps up.

(U) A. Mission Description and Budget Item Justification

This project develops technology to increase turbine engine operational reliability, durability, mission flexibility, and performance, while reducing weight, fuel consumption, and cost of ownership. Analytical and experimental areas of emphasis are fans and compressors, high temperature combustors, turbines, internal flow systems, controls, augmentor and exhaust systems, integrated power and thermal management systems, engine inlet integration, mechanical systems, and structural design. This project supports the IHPTET and VAATE programs, which are joint DoD, NASA, and industry efforts to focus turbine propulsion technology on national needs. The program plan reflects the technology base support for VAATE activity applicable to global responsive strike, capable unmanned warfighting, tactical and global mobility, responsive space lift, and persistent Intelligence, Surveillance, and Reconnaissance.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2004	FY 2005	FY 2006	FY 2007
(U) MAJOR THRUST: Develop core turbofan/turbojet engine components (i.e., compressors, combustors, and high-pressure turbines) for fighters, bombers, sustained supersonic/hypersonic cruise vehicles, and transports. Note: In FY 2005, funding shifts from IHPTET core engine efforts to VAATE component and technology efforts in this project. In FY 2006, efforts will further develop advanced concepts, designs, design rules, and computational tools to increase efficiency and operability, decrease weight, and improve durability of axial compressors, combustors, and high pressure turbines (HPT), as well as improve pattern factor and decrease harmful emissions of combustors, and increase HPT cooling effectiveness. These efforts enable aircraft engines with higher performance, increased durability, reduced fuel consumption, and lower life cycle cost.	23.981	16.640	16.970	16.708

(U) In FY 2004: Completed airfoil design for a high-pressure ratio compressor to study unsteady flow interactions for reduced fuel burn, and high reaction blading and engine stall avoidance techniques for reduced maintenance cost. Completed preliminary full annular aerothermal tests of a trapped vortex combustor. Conducted design and began fabrication of advanced high-pressure turbine rig hardware to evaluate advanced three-dimensional effects on blade tip heat transfer for increased performance and durability. Developed advanced intentional mistuning methodology and began experimental verification on transonic rig hardware.

(U) In FY 2005: Rig test a high-pressure ratio compressor including an assessment of unsteady flow interactions for reduced fuel burn, and high reaction blading and engine stall avoidance techniques for reduced maintenance cost. Conclude full annular aerothermal tests of a trapped vortex combustor. Rig

test an integrated lightweight combustor with a ceramic matrix composite shell and advanced material panels representative of advanced combustor configurations. Complete fabrication and test advanced high-pressure turbine rig hardware to evaluate advanced three-dimensional effects on blade tip heat transfer for increased performance and durability. Enhance advanced intentional mistuning methodology and complete experimental verification on transonic rig hardware.

(U) In FY 2006: Develop and apply advanced modeling and simulation rules and tools for advanced components (high cycle fatigue, computational fluid dynamics, cycle analyses, propulsion system models, component life models, probabilistic models, etc.). Incorporate advanced materials systems into innovative designs (gamma titanium aluminides, metal matrix composites, ceramics, new metallic alloys, etc.). Develop and extend analytical methods to predict integrally bladed rotor and airfoil durability, and damage tolerance. Conduct bench and rig tests of advanced components for validation, such as an advanced metal foam heat exchanger.

(U) In FY 2007: Continue to develop and apply advanced modeling and simulation rules and tools for advanced components. Incorporate advanced materials systems into innovative designs and analyze Ceramic Matrix Composite turbine blades, turbine vanes, and turbine rear frame. Design and analyze tiled turbine airfoil technology to reduce cooling flow and increase life. Design and demonstrate a very short, high efficiency afterburner concept. Conduct rig tests and design optimization of effective, durable, radiation barrier coatings to reduce the radiant heat loads on hot section components. Design, fabricate, and rig test fan/radial compressor internal aerodynamics, large radius rotating air seals, a low profile annular combustor, and a large scale casting of fan/radial compressor.

(U)

(U)	MAJOR THRUST: Develop turbofan/turbojet engine components (i.e., fans, low pressure turbines, engine controls, exhaust nozzles, and integration technologies) for turbofan/turbojet engines for fighters, bombers, sustained supersonic strike and hypersonic cruise vehicles, and transports. Note: In FY 2006, funding increases to support new focus to further develop advanced concepts, designs, design rules, and computational tools to increase efficiency and operability, decrease weight, and improve durability of fans, low pressure turbines (LPT), control systems, augmentors, and exhaust nozzles, as well as increase LPT cooling effectiveness, increase control systems parameters and response, and reduce augmentors observability and screech. These efforts enable aircraft engines to have higher performance, increased durability, reduced fuel consumption, and lower life cycle cost.	6.915	10.419	10.626	10.461

(U) In FY 2004: Completed preliminary design of an advanced tandem, forward swept fan incorporating hybrid blade construction and composite reinforced disks to achieve high efficiency and stage loading with reduced weight and cost. Performed three-dimensional computational fluid dynamics (CFD) analysis and detailed design of multi-stage low pressure turbine rig hardware to assess performance of advanced turbine blade configurations applicable to high altitude, long endurance systems. Performed

initial tests of advanced control system hardware using component life models to verify real-time computational capabilities for transitioning this technology to a demonstrator engine program. Conducted base analysis and tests of advanced, low-observable compatible augmentor designs, resulting in improved design rules and tools to improve augmentor operability and reduce screech.

(U) In FY 2005: Perform post-test analysis of multi-stage low-pressure rig test data to assess performance of advanced turbine blade configurations applicable to high altitude, long endurance systems. Conclude testing advanced control system hardware using component life models to verify real-time computational capabilities for transitioning this technology to a demonstrator engine program. Conclude analysis and tests of advanced, low-observable compatible augmentor designs, resulting in improved design rules and tools to improve augmentor operability and reduce screech. Note: In FY 2005, the refocusing of Air Force turbine efforts to complete the IHPTET by FY 2005 caused the advanced tandem, forward swept fan activity to be eliminated in favor of other critical elements.

(U) In FY 2006: Develop and apply advanced modeling and simulation rules and tools for advanced components (high cycle fatigue, computational fluid dynamics, cycle analyses, propulsion system models, component life models, probabilistic models, etc.). Apply advanced materials systems to innovative designs (gamma titanium aluminides, metal matrix composites, ceramics, advanced metallic alloys, etc.). Develop new and innovative design concepts, and conduct bench and rig tests of advanced components for validation.

(U) In FY 2007: Identify and quantify sources of variability and uncertainty affecting turbine blade durability performance (oxidation, creep, thermal material fatigue, high cycle fatigue, etc.). Apply advanced materials systems to innovative designs to determine wear reduction, improve load capacity, and increase temperature capability of five centi-stokes oil and to assess aerodynamics, operability, aeromechanics, and acoustic characteristics of a counter-rotating fan-on-blade (FLADE) concept. Conduct design optimization for turbine blade microcircuit cooling. Test pilot and fuel injection concepts in a single-flameholder rig to evaluate fundamental capabilities.

(U)

(U) MAJOR THRUST: Develop limited life engine components for missile and unmanned air vehicle applications, including long-range supersonic and hypersonic vehicles. Note: In FY 2006, funding increases to support new focus to further develop advanced concepts, designs, design rules, and computational tools for the complete range of small and mid-size turbine engine applications. These efforts enable engines with reduced cost, reduced fuel consumption, and increased specific thrust, thereby greatly expanding the operating envelopes of missiles and unmanned vehicles.	0.294	3.313	3.378	3.327

(U) In FY 2004: Completed preliminary conceptual design and conducted configuration studies of an advanced versatile and affordable high-pressure core and engine component configurations for expendable engines using rub tolerant ceramic blades to meet the small engine performance and cost

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reduction objectives.

(U) In FY 2005: Complete configuration studies and continue conceptual design of an advanced versatile and affordable high-pressure core and low-pressure component configurations for expendable engines using rub tolerant ceramic blades to meet the small engine performance and cost reduction objectives.

(U) In FY 2006: Complete conceptual design of an advanced versatile and affordable high-pressure core and low-pressure component configurations for expendable engines using rub tolerant ceramic blades to meet the small engine performance and cost reduction objectives. Apply advanced materials systems to innovative designs and analyze a slinger-fed, dual-fuel compact recirculation combustor (CRC). Develop and apply advanced modeling and simulation rules and tools for advanced components (i.e.; high cycle fatigue (HCF), computational fluid dynamics (CFD), cycle analyses, propulsion system models, component life models, probabilistic models, etc.). Complete detailed design, computational fluid dynamics, and perform analyses for a fuel-cooled turbine. Develop new and innovative design concepts, and conduct bench and rig tests of advanced components for validation.

(U) In FY 2007: Rig test a slinger-fed, dual-fuel CRC. Continue to develop and apply advanced modeling and simulation rules and tools for advanced components (Ie;high cycle fatigue, computational fluid dynamics, cycle analyses, propulsion system models, component life models, probabilistic models, etc.). Rig test a fuel-cooled turbine. Design and analyze a five-stage forward swept compressor.

(U)

(U) MAJOR THRUST: Develop components for turboshaft/turboprop and small turbofan engines for trainers, rotorcraft, special operations aircraft, and theater transports. Note: In FY 2006, funding increases to support new focus to further develop advanced concepts, designs, design rules, and computational tools for the complete range of turboshaft/turboprop turbine engine applications.	0.151	1.099	1.121	1.104

(U) In FY 2004: Began conceptual design and conducted configuration studies of advanced versatile and affordable high-pressure compressor, combustor, and high-pressure turbine configurations for turboshaft/turboprop engines to meet the small engine performance and cost reduction objectives.

(U) In FY 2005: Enhance conceptual design of advanced versatile and affordable high-pressure core engine component configurations for turboshaft/turboprop engines to meet the small engine performance and cost reduction objectives.

(U) In FY 2006: Develop and apply advanced modeling and simulation rules and tools for advanced components (i.e.; HCF, CFD, cycle analyses, propulsion system models, component life models, probabilistic models, etc.). Complete conceptual design of advanced versatile and affordable high-pressure core engine component configurations for turboshaft/turboprop engines to meet the small engine performance and cost reduction objectives. Apply advanced materials systems to design and analyze a high heat release combustor. Develop new and innovative design concepts and conduct bench and rig tests of advanced components for validation.

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(U)	In FY 2007: Continue to develop and apply advanced modeling and simulation rules and tools for advanced components. Apply advanced materials systems to innovative designs and analyze a nano-laminate thermal barrier coating. Develop new and innovative design concepts and conduct bench and rig tests of advanced components for validation such as a high heat release combustor.				
(U)					
(U)	CONGRESSIONAL ADD: VAATE-Titanium Matrix Composites.	0.000	0.991	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Apply Titanium Matrix Composite materials to an advanced fan design with the goal of increasing performance and/or reducing weight.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Center for Flow Physics and Control.	0.000	1.883	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Conduct experimental and analytical studies to determine optimal diagnostic configuration for new high-speed sensors and actuators to evaluate gaseous flow through a turbine engine. Use results to design more accurate and effective laboratory test facility for engine design.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)	Total Cost	31.341	34.345	32.095	31.600

(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) Related Materials:										
(U) PE 0601102F, Defense Research Sciences.										
(U) PE 0602102F, Materials.										
(U) PE 0603216F, Aerospace Propulsion and Power Technology.										
(U) PE 0602122N, Aircraft Technology.										
(U) PE 0603210N, Aircraft Propulsion.										

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

(U) PE 0603003A, Aviation Advanced Technology. This project has been coordinated through the

(U) Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.

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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
3145	Aerospace Power Technology	36.155	44.152	30.134	29.025	31.144	33.201	33.724	34.203	Continuing	TBD
	Quantity of RDT&E Articles	0	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

This project develops techniques for efficient energy conversion/storage, power generation/power conditioning/distribution, and thermal management for military aerospace applications. Power component technologies are developed to increase reliability, maintainability, commonality, and supportability of aircraft and flight line equipment. Research is conducted in energy storage technologies to enable the 10-20 year long-term energy storage goals of Air Force unmanned vehicles. Electrical power generation/power conditioning/distribution and thermal management technologies enable all future military directed energy weapon systems. This project supports development of very high output power systems suitable for applications to air moving target indication radar, high power lasers, and high power microwaves for aerospace platforms. Lightweight power systems suitable for other aerospace applications are also developed.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2004	FY 2005	FY 2006	FY 2007
(U) MAJOR THRUST: Develop power generation/conditioning/distribution, energy conversion/storage, and thermal management component and subsystem technologies for manned and unmanned aircraft systems. These technologies improve aircraft self-sufficiency, reliability, maintainability, and supportability, while reducing life cycle costs and enabling new capabilities.	12.502	11.987	11.400	10.866
(U) In FY 2004: Tested an advanced-switched reluctance machine controller. Initiated development of lithium-based solid state electrolyte battery technology. Performed a dynamometer test of a starter/generator applicable for mid-thrust class turbine engine high spool applications.				
(U) In FY 2005: Fabricate and test small-scale lithium-based solid state cells. Fabricate and test modular fuel cell systems for manned and unmanned vehicles. Verify dynamic engine models for power extraction through data analysis by independent model. Complete testing of an advanced switched reluctance machine controller.				
(U) In FY 2006: Develop next generation solid state lithium-based electrolyte and develop thin film cells with high voltage battery cathodes. Perform system design and analysis and develop breadboard of a high power fuel cell system for manned and unmanned vehicles.				
(U) In FY 2007: Fabricate and characterize next generation solid state lithium-based thin film cells.				
(U)				
(U) MAJOR THRUST: Develop thermal management, energy conversion/storage and power conditioning components, and subsystem technologies for aerospace applications.	2.612	2.870	4.276	4.003
(U) In FY 2004: Developed integrated vehicle health monitoring algorithms. Studied advanced packaging techniques for silicon carbide power electronics.				
(U) In FY 2005: Integrate vehicle health monitoring algorithms into power distribution unit. Fabricate and begin testing a silicon carbide packaging concept for power electronic device development.				

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(U)	In FY 2006: Complete testing a silicon carbide packaging concept for power electronic device development. Initiate efforts to scale-up sub-scale spray cooling flight tests to ten kW and expand modeling efforts to support the scale-up. Develop flight experiment for two-phase active thermal management system.				
(U)	In FY 2007: Complete scale-up, modeling efforts and flight tests of ten kW spray cooling technology.				
(U)					
(U)	MAJOR THRUST: Develop cryogenic power generation, high rate batteries, energy conversion/storage and power conditioning components, and system technologies with low volume displacement to enable delivery of high power for operation of directed energy weapons. Note: In FY 2006, increase in funding is due to fabrication and test of superconducting generator.	8.650	9.868	14.458	14.156
(U)	In FY 2004: Designed and fabricated advanced capacitors for pulsed power applications. Fabricated and began testing liquid dielectric high voltage switches. Optimized processing techniques for long length Bismuth Strontium Calcium Copper Oxide (BSCCO)/Yttrium Barium Copper Oxide (YBCO) high temperature superconducting components. Fabricated and tested small-scale, high rate lithium-ion cells.				
(U)	In FY 2005: Test advanced pulse power capacitors. Complete testing liquid dielectric high voltage switches. Test BSCCO/YBCO superconducting coils in a rotating test rig for megawatt-class power applications. Scale-up and test high rate lithium-ion (liquid) cells. Initiate preliminary design of proof-of-concept superconducting generator.				
(U)	In FY 2006: Develop conductor configuration, test, and deliver a coil of alternating current tolerant high temperature superconducting material. Initiate preliminary design of high rate lithium-ion (liquid) battery system for directed energy applications. Complete design of proof-of-concept superconducting generator and begin fabrication.				
(U)	In FY 2007: Continue design of high rate lithium-ion (liquid) battery system for directed energy applications. Complete fabrication and begin testing proof-of-concept superconducting generator.				
(U)					
(U)	CONGRESSIONAL ADD: High-Power, Advanced Low-Mass (HPALM).	2.439	0.000	0.000	0.000
(U)	In FY 2004: Designed, fabricated, and tested prototype components supporting a five kW HPALM solar-thermionic power system ground demonstration, including inflatable concentrator, thermionic inverted converter, secondary concentrator, thermal receiver with thermal storage, and high temperature power conditioning. Investigated integration of prototype components as an initial ground demo system analysis. Conducted performance and mission analysis of a conceptual 50kW HPALM space power system based on prototype data.				
(U)	In FY 2005: Not Applicable.				
(U)	In FY 2006: Not Applicable.				

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(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Cell-Level Battery Control. Note: In FY 2004, only for SBIR Phase 3 cell level battery controller development.	0.976	1.486	0.000	0.000
(U)	In FY 2004: Designed, fabricated, and tested initial prototype components for monitoring and controlling charge and temperature of battery energy storage systems of battery controller for lithium ion battery in man-portable systems to address cell level charge and thermal management.				
(U)	In FY 2005: Further develop and improve prototype components for monitoring and control of charge and temperature of battery energy storage systems of battery controller for lithium ion battery in man-portable systems and expand efforts to airborne systems.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Lightweight Photovoltaics for Portable Power and Hydrogen Generation. Note: In FY 2005, this was referred to as "Photovoltaic Hydrogen and Flexible Photovoltaic for Portable Power."	0.976	0.991	0.000	0.000
(U)	In FY 2004: Investigated various photovoltaic solar cells to determine performance characteristics. Designed, fabricated, tested, and integrated photovoltaic solar cells with a water electrolizer to generate hydrogen. Photovoltaics will be integrated into solar cell technology with a water electrolizer to generate hydrogen. This hydrogen can be used in a fuel cell to support applications ranging from low power special operations to high power, high altitude airships and long endurance unmanned aerial vehicles.				
(U)	In FY 2005: Continue to investigate various photovoltaic solar cells to determine performance characteristics. Evaluate device designs to incorporate accomplishments from prior years. Determine designs most likely for success and produce a final design based on this determination.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Hypersonic Vehicle Electric Power System (HVEPS) Technology.	2.145	3.073	0.000	0.000
(U)	In FY 2004: Designed, fabricated, and tested a small 10-100 kilowatt (kW) demonstration magnetohydrodynamic (MHD) generator. This demonstration included the use of high temperature ceramic electrodes and modern commercial cryocoolers with superconducting magnets that were integrated, but thermally isolated from the high temperature MHD channel with active cooling.				
(U)	In FY 2005: Fabricate and test subscale 500 kW supersonic and 100 kW hypersonic MHD generators using modern commercial cryocoolers for the MHD superconducting magnets and high energy fuels to produce high temperatures and electrical conductivity in the MHD channel.				

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(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: High Powered Electrical Aircraft Capabilities (HiPEAC).	2.927	6.443	0.000	0.000
(U)	In FY 2004: Performed system analyses of high-powered electrical systems including investigation of integrated subsystems and various component technologies. Designed, fabricated, and tested prototype components that are critical to high-powered electrical systems. HiPEAC is an electrical power system demonstrator and test bed that supports current and future high power systems, thus enabling new sensor, communications, and directed energy applications.				
(U)	In FY 2005: Identify the technologies required to satisfy the capability requirements of emerging high-powered aircraft. Complete designs, fabrication, and tests of critical technologies required for enabling new platform capabilities. Develop and build a ground-based aircraft electric power test bed to demonstrate system level and component level technologies and drive them to mature technology readiness levels.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Center for Security of Large-Scale Systems.	2.928	1.883	0.000	0.000
(U)	In FY 2004: Developed accurate, high-speed computations for the implementation of fast-acting on-line control to enhance security and survivability of military installations and applications. Developed advanced distributed heterogeneous simulation techniques and implemented their application to the security of large-scale systems (LSS). Configured and exercised predictive simulations, and developed and tested prototype hardware to verify and validate the modeling and simulation accuracy.				
(U)	In FY 2005: Improve previous and develop new accurate, high-speed computation for the implementation of fast-acting on-line control to enhance security and survivability of military platforms with specific focus on the application of advanced distributed heterogeneous simulation techniques to LSS. Expand and conduct tests of prototype hardware used to verify and validate the modeling and simulation accuracy.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Remote-Base Power Demonstration.	0.000	1.486	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Develop materials systems and cell-stack configurations for increasing the power density and improving start-up characteristics for a five kW Auxiliary Power Unit using advanced solid oxide				

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	fuel cell technology.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Integrated Cooling and Power System with Magnetic Bearing Turbogenerator.	0.000	2.776	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Analyze, model, and develop the system components comprising a complete Integrated Cooling and Power System (ICPS), integrate the Magnetic Bearing Turbo-Generator (MBTG) with these components, and perform system-level ground tests of the entire MBTG-enabled ICPS package.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Advanced Cooling Technology for High Flux Military Diode Laser Arrays.	0.000	1.289	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Conduct scaling, reliability, and flight test experiments to advance spray-cooling concepts for high flux laser components for space and air vehicles.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)	Total Cost	36.155	44.152	30.134	29.025

(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) Related Activities:										
(U) PE 0601102F, Defense Research Sciences.										
(U) PE 0602102F, Aerospace Flight Dynamics.										
(U) PE 0602605F, Directed Energy Technology.										
(U) PE 0602805F, Dual Use Science and Technology.										
(U) PE 0603605F, Advanced Weapon Technology.										

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

(U) PE 0603216F, Aerospace Propulsion and Power Technology.

(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification

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BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602203F Aerospace Propulsion

PROJECT NUMBER AND TITLE: 4847 Rocket Propulsion Technology

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
4847	Rocket Propulsion Technology	24.578	25.229	12.047	14.506	10.969	11.466	11.592	11.701	Continuing	TBD
	Quantity of RDT&E Articles	0	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

This project develops technologies for the sustainment of strategic systems (including solid boost/missile propulsion, post boost control, aging and surveillance efforts) and tactical rockets. Technologies of interest will improve reliability, performance, survivability, affordability, and environmental compatibility of these systems. Technologies are being accomplished in two phases and are developed to reduce the weight by 15 percent (Phase I)/20 percent (Phase II) and cost of components 25 percent (Phase I)/30 percent (Phase II) through the use of new materials, and improving designs and manufacturing techniques. Aging and surveillance efforts could improve lifetime prediction capabilities by 10 years and reduce non-destructive test costs by 50 percent. All efforts in this project are part of the Technology for the Sustainment of Strategic Systems program and support the Integrated High Payoff Rocket Propulsion Technology program.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2004	FY 2005	FY 2006	FY 2007
(U) MAJOR THRUST: Develop missile propulsion, aging, and surveillance technology for solid rocket systems for Intercontinental Ballistic Missile to include testing missile propulsion technology and Post Boost Control Systems (PBCS). Efforts support the Technology for the Sustainment of Strategic Systems program - Phase I. Note: In FY 2005, these efforts were moved to the Advanced Technology Development efforts in PE 0603216F, Project 4922.	2.248	0.000	0.000	0.000
(U) In FY 2004: Completed risk reduction efforts supporting the Phase I missile propulsion demonstration. Completed Phase I full-scale risk reduction component development and test to support the advanced PBCS demonstration.				
(U) In FY 2005: Not Applicable.				
(U) In FY 2006: Not Applicable.				
(U) In FY 2007: Not Applicable.				
(U)				
(U) MAJOR THRUST: Develop missile propulsion and boost technologies for tactical and ballistic missile systems. Efforts support the Technology for the Sustainment of Strategic Systems program - Phase II.	10.199	9.009	10.615	7.301
(U) In FY 2004: Conducted component development and risk reduction efforts for the Phase II ballistic missile technology demonstration. Furthered development of rapid densification nozzle technology, using improved strategic propellants for future ballistic missiles to enhance performance and weight. Demonstrated low-cost, high temperature, non-erosive, lightweight coated carbon-carbon ceramic and hybrid polymer components for solid rocket motors. Improved the formulation and characterization of new propellant formulations using new fuels and oxidizers developed the last couple years for the next phase of advanced solid propulsion. Completed preliminary development and updates to solid rocket motor modeling and simulation tools to improve industry capability to design ballistic missile				

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components (cases, nozzles, insulation, etc.) and motors.

(U) In FY 2005: Enhance component development and risk reduction efforts for the Phase II ballistic missile technology demonstration. Continue development of rapid densification nozzle technology, using improved strategic propellants for future ballistic missiles to enhance performance and weight. Continue demonstrating low-cost, high temperature, non-erosive, lightweight coated carbon-carbon ceramic and hybrid polymer components for solid rocket motors. Continue formulating and characterizing new propellant formulations using new fuels and oxidizers developed the last couple years for the next phase of advanced solid propulsion. Continue modeling and simulation tool developments for solid rocket motors. Continue development of advanced tactical propulsion components. Note: The FY 2005 start of component development for the propulsion demonstration efforts was delayed to allow completion of modeling and simulation tools, these tools will be used in the design of the new components.

(U) In FY 2006: Enhance component development and risk reduction efforts for the Phase II ballistic missile technology demonstration. Continue development of rapid densification nozzle technology using improved strategic propellants for future ballistic missiles to enhance performance and weight. Continue demonstrating low-cost, high temperature, non-erosive, lightweight coated carbon-carbon ceramic and hybrid polymer components for solid rocket motors. Complete formulation and characterization of new propellant formulations using new fuels and oxidizers developed over the last couple of years for the next phase of advanced solid propulsion. Continue modeling and simulation tool developments for solid rocket motors to be used in developing components for the Phase II Missile Propulsion Demonstration. Continue development of advanced tactical propulsion technologies.

(U) In FY 2007: Initiate component development and risk reduction efforts for the Phase II Missile Propulsion demonstration. Verify development of rapid densification nozzle technology using improved strategic propellants for future ballistic missiles to enhance performance and weight. Continue demonstrating low-cost, high temperature, non-erosive, lightweight coated carbon-carbon, ceramic and hybrid polymer components for solid rocket motors. Continue development of advanced tactical propulsion technologies. Complete modeling and simulation tool developments for solid rocket motors to be used in developing components for the Phase II Missile Propulsion Demonstration.

(U)

(U) MAJOR THRUST: Develop missile propulsion technologies and aging and surveillance technologies for ballistic missile. Efforts support the Technology for the Sustainment of Strategic Systems program Phase II.	1.596	1.798	1.432	7.205

(U) In FY 2004: Initiated Phase II aging and surveillance technology developments in analysis codes, tools, and inspection tools for improved assessment of ballistic missile aging characteristics and status.

(U) In FY 2005: Continue Phase II aging and surveillance technology developments in analysis codes, tools, and inspection tools for improved assessment of ballistic missile aging characteristics and status.

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(U)	In FY 2006: Complete analysis of existing sensor technologies for use in assessment of ballistic missile aging characteristics and status. Initiate an advanced service life prediction technology program developing and applying existing and advanced sensors that can be embedded or attached to solid rocket motors and the aging and surveillance models and tools that can translate and integrate the sensor data into existing aging and surveillance tool suite.				
(U)	In FY 2007: Continue advanced service life prediction technology program developing and applying existing and advanced sensors that can be embedded or attached to solid rocket motors and the aging and surveillance models and tools that can translate and integrate the sensor data into existing aging and surveillance tool suite.				
(U)					
(U)	CONGRESSIONAL ADD: Hybrid Plastics.	0.976	0.000	0.000	0.000
(U)	In FY 2004: Built a pilot plant for the scale-up of Polyhedral Oligomeric Silsesquioxane (POSS) polymers producing much larger quantities at much cheaper prices and accelerating the further development and application of this new class of polymers for applications in liquid and solid rocket engines and spacecraft engines.				
(U)	In FY 2005: Not Applicable.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Engineering Tool Improvement Program (ETIP). Note: Efforts expand upon activities initiated in a FY 2003 Congressional Add in PE 0602500F, Project 5026. In FY 2005, this effort was continued as a Congressional Add in PE 0602500F, Project 5026.	4.194	0.000	0.000	0.000
(U)	In FY 2004: Developed and improved modeling and simulation tools to address spacecraft component interactions and solid rocket motor component contributions and technology payoffs. Developed improvements identified from previous work for liquid engine system modeling and simulation tools.				
(U)	In FY 2005: Not Applicable.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Integrated High Payoff Rocket Propulsion Technology.	0.976	0.000	0.000	0.000
(U)	In FY 2004: Conducted risk reduction efforts in the Technology for the Sustainment of Strategic Systems program Phase I seeking a 25 percent cost reduction and 5:1 turndown ratio of a Post Boost Control Propulsion System using sustainable materials.				
(U)	In FY 2005: Not Applicable.				
(U)	In FY 2006: Not Applicable.				

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(U) In FY 2007: Not Applicable.				
(U)				
(U) CONGRESSIONAL ADD: Advanced Vehicle and Propulsion Center. Note: For a common Air Force Research Laboratory/Space and Missile Systems Center product center co-located with the Rocket Propulsion Laboratory.	4.389	3.965	0.000	0.000
(U) In FY 2004: Provided technical support for the analysis of alternatives (AOA) for the following key Air Force missions: prompt global strike; land-based strategic deterrent; and operationally responsive space lift.				
(U) In FY 2005: Continue technical support for the AOA for the following key Air Force missions: prompt global strike; land-based strategic deterrent; and operationally responsive space lift.				
(U) In FY 2006: Not Applicable.				
(U) In FY 2007: Not Applicable.				
(U)				
(U) CONGRESSIONAL ADD: Jet and Rocket Engine Test Site (JRETS) testing at San Bernardino International Airport. Note: Efforts expand upon activities in a FY 2004 Congressional Add in PE 0602500F, Project 5026.	0.000	6.740	0.000	0.000
(U) In FY 2004: Not Applicable.				
(U) In FY 2005: Expand the test capabilities to include a spacecraft environmental testing capability and upgrade test capabilities at each test stand.				
(U) In FY 2006: Not Applicable.				
(U) In FY 2007: Not Applicable.				
(U)				
(U) CONGRESSIONAL ADD: Advanced Aerospace Vehicle Cooling Technologies. Note: Only to conduct evaluations of aerospace vehicle cooling technologies at the JRETS rockets test stand at the San Bernardino International Airport.	0.000	0.991	0.000	0.000
(U) In FY 2004: Not Applicable.				
(U) In FY 2005: Commence Congressionally-directed effort for evaluating aerospace vehicle cooling technologies.				
(U) In FY 2006: Not Applicable.				
(U) In FY 2007: Not Applicable.				
(U)				
(U) CONGRESSIONAL ADD: Aerospace Lab Equipment Upgrade.	0.000	0.991	0.000	0.000
(U) In FY 2004: Not Applicable.				
(U) In FY 2005: Obtain subsonic wind tunnel equipment for university educational and research purposes.				
(U) In FY 2006: Not Applicable.				

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(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: High Regression Rate Hybrid Rocket Fuels.	0.000	0.744	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Conduct analytical and experimental studies to evaluate the feasibility to mature high regression rate hybrid rocket fuels for use in space launch vehicles.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)					
(U)	CONGRESSIONAL ADD: Engineering Research Laboratory Equipment Upgrade.	0.000	0.991	0.000	0.000
(U)	In FY 2004: Not Applicable.				
(U)	In FY 2005: Obtain mechanical engineering equipment for university educational and research purposes.				
(U)	In FY 2006: Not Applicable.				
(U)	In FY 2007: Not Applicable.				
(U)	Total Cost	24.578	25.229	12.047	14.506

(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) Related Activities:										
(U) PE 0601102F, Defense Research Sciences.										
(U) PE 0602114N, Power Projection Applied Research.										
(U) PE 0602303A, Missile Technology.										
(U) PE 0602500F, Multi-Disciplinary Space Tech.										
(U) PE 0603311F, Ballistic Missile Technology.										
(U) PE 0603401F, Advanced Spacecraft Technology.										
(U) This project has been coordinated through the										

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

Reliance process to harmonize efforts and eliminate duplication.

(U) D. Acquisition Strategy

Not Applicable.