PE NUMBER: 0601102F
PE TITLE: Defense Research Sciences

Exhibit R-2, RDT&E Budget Item Justification

DATE: February 2004

BUDGET ACTIVITY: 01 Basic Research

PE NUMBER AND TITLE: 0601102F Defense Research Sciences

	Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
	Total Program Element (PE) Cost	211.559	212.897	217.304	230.536	256.246	245.626	248.537	0.000	0.000
2301	Physics	23.487	25.749	23.690	23.904	27.774	24.828	25.199	0.000	0.000
2302	Solid Mechanics and Structures	11.236	11.641	13.276	14.873	16.594	17.314	18.535	0.000	0.000
2303	Chemistry	27.987	27.939	29.292	28.531	31.485	28.218	28.698	0.000	0.000
2304	Mathematical and Computer Sciences	31.286	29.293	25.663	34.397	39.314	35.952	32.022	0.000	0.000
2305	Electronics	23.234	25.041	25.174	26.833	29.722	29.674	30.117	0.000	0.000
2306	Materials	14.170	15.035	15.917	15.971	17.704	17.538	17.871	0.000	0.000
2307	Fluid Mechanics	10.025	12.875	10.902	10.997	11.715	11.426	11.630	0.000	0.000
2308	Propulsion	22.554	15.660	15.864	16.918	17.791	17.675	18.053	0.000	0.000
2311	Space and Information Sciences	14.681	20.379	24.661	23.286	22.523	22.868	23.660	0.000	0.000
2312	Biological Sciences	13.605	9.272	9.631	9.756	13.443	10.279	10.526	0.000	0.000
2313	Human Performance	12.332	12.667	13.596	13.655	14.412	14.105	14.319	0.000	0.000
4113	External Research Programs Interface	6.962	7.346	9.638	11.415	13.769	15.749	17.907	0.000	0.000

Note: In FY 2005, Project 2311, "Space Sciences," changed its name to "Space and Information Sciences."

(U) A. Mission Description and Budget Item Justification

This program consists of extramural research activities in academia and industry along with in-house investigations performed in the Air Force Research Laboratory. This program funds fundamental broad-based scientific and engineering research in areas critical to Air Force weapon systems. Projects are coordinated through the Defense Reliance process to harmonize efforts, eliminate duplication, and ensure the most effective use of funds across the Department of Defense. All research areas are subject to long-range planning and technical review by both Air Force and tri-Service scientific planning groups. Note: In FY 2004, Congress added $1.0 million for Advanced Adaptive Optics, $1.7 million for National Fotonics Research, $0.5 million for Non-lethal Stunning/Immobilizing Weapons Research, $1.0 million for Corrosion Protection of Aluminum Alloys Used in Aircraft, $1.4 million for Thin Film Magnetic Materials, $2.0 million for the National Hypersonic Research Center, $2.55 million for Coal-Based Jet Fuel, $2.0 million for the Chabot Space and Science Center, $1.1 million for Quantum Information Technology, and $1.8 million for Information Security and Cyber Counter Terrorism.

Exhibit R-2, RDT&E Budget Item Justification	DATE February 2004
BUDGET ACTIVITY 01 Basic Research	PE NUMBER AND TITLE 0601102F Defense Research Sciences

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

		FY 2003	FY 2004	FY 2005
(U)	Previous President's Budget	217.863	204.754	218.188
(U)	Current PBR/President's Budget	211.559	212.897	217.304
(U)	Total Adjustments	-6.304	8.143	
(U)	Congressional Program Reductions		-5.080	
	Congressional Rescissions		-1.827	
	Congressional Increases		15.050	
	Reprogrammings	-0.076		
	SBIR/STTR Transfer	-6.228		

(U) Significant Program Changes:

Changes to this program since the previous President's Budget are a result of higher Air Force priorities.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2301 Physics	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2301 Physics	23.487	25.749	23.690	23.904	27.774	24.828	25.199	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Physics basic research aims to revolutionize advances in and expand the fundamental knowledge supporting laser technologies, sensors and imaging, miniature satellites, optics, electro-energetics, and communications to allow superior strategic awareness. The goals are to enable and enhance technologies critical to Air Force lasers, optics, avionics, and microwaves and to improve technologies associated with non-intrusive/non-destructive testing and analysis. Research topics focus on revolutionary improvements in electromagnetic countermeasures, communications, small satellites, and novel sensors. The primary areas of research investigated by this project are laser and optical physics; electro-energetics (includes plasma) physics; atomic, molecular, and particle physics; and space sensors and imaging (includes environment interactions) physics.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Investigate regulated, broad-spectrum, variable-energy lasers, laser arrays, and multi-aperture adaptive optics.	8.785	9.987	8.223

(U) In FY 2003: Studied combining high power solid state lasers with integrated nonlinear and pulse forming optics. Investigated concepts to achieve laser high output powers at wavelengths required for space applications. Explored large, lightweight adaptive optics and large aperture telescopes for very high-resolution space surveillance and imaging applications. Studied laser micro-machining techniques for producing specialized space micro-systems for multi-functional micro- and nano-satellites.

(U) In FY 2004: Expand studies of high power fiber lasers, in particular those using novel material combinations, which support large-core, single-mode fibers. Investigate direct and nonlinear optical methods for combining beams of fiber lasers to achieve power levels needed for multiple directed energy applications. Continue research to convert wavelengths of high-power laser arrays to values needed for space applications and aircraft protection. Expand studies of large, lightweight adaptive optics and large aperture telescopes for very high-resolution space surveillance and imaging applications. Extend studies of large aperture adaptive telescopes for very high-resolution deep space imaging. Study new optical techniques to achieve very large aperture, very wide-band phased array radars in space. Study laser micro-machining techniques for producing specialized micro- and nano-components for multi-functional micro- and nano-satellites.

(U) In FY 2005: Continue investigating physical properties of lasers to enable, monitor, and regulate tunable, wide wavelength band lasers (e.g., solid state, free electron, fiber). Investigate novel tomographic and optical techniques tied to large, multi-aperture, adaptive telescopes and radars. Expand studies of novel laser micro-and nano-machining techniques and their applications to new materials with desirable space and electronic properties. Explore laser

Exhibit R-2a, RDT&E Project Justification			DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2301 Physics**	

	applications for infrared countermeasures.			
(U)				
(U)	MAJOR THRUST: Explore high-energy electro-energetic devices, communication systems, surveillance and countermeasure platforms, and aerodynamic systems to facilitate creation of better propellants and more capable directed energy weapons. Note: In FY 2005, these activities will be moved to the "atoms, molecules, and particles" efforts in this Project.	8.133	8.012	0.000
(U)	In FY 2003: Researched plasma physics to investigate fundamental interactions between charged particles and electromagnetic fields for future directed energy weapons, affordable low-observables, and space communications and surveillance. Explored physics governing dynamic molecular interactions in combustion and high energy density propellants. Examined the detailed physics of material, surface, and air breakdown in the presence of strong electric fields.			
(U)	In FY 2004: Enhance research studies in plasma physics to investigate fundamental interactions between charged particles and electromagnetic fields for all-electric military platforms, high-bandwidth communications, advanced long-distance covert surveillance, and space communications and surveillance. Expand research into the physics of molecular interactions in combustion and high energy density propellants. Continue examining the detailed physics of material, surface, and air breakdown in the presence of strong electric fields to facilitate creation of more compact, lighter weight, portable pulsed power systems in order to power future directed energy weapons. Expand the understanding of short-pulse intense electric fields' effects on cells and organelles.			
(U)	In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to the "atoms, molecules, and particles" efforts in this Project.			
(U)				
(U)	MAJOR THRUST: Manipulate atomic and molecular properties, atomic collision processes, and atomic, molecular, ionic, and radiation interactions to improve explosives and fuels, advance directed energy systems, enhance surveillance, provide superior communications, and improve precision navigation.	4.646	1.295	11.422
(U)	In FY 2003: Investigated fundamental interplay between atoms and strong electromagnetic fields to identify potentially new classes of lasers. Completed isomeric, high energy density storage for flash radiation devices to diminish or eliminate refueling requirements on long endurance flights. Furthered research of holographic films for correction of distortion and aberration in space surveillance telescopes. Commenced measuring ultraviolet emission cross sections from electron impact to provide fundamental data needed in satellite surveillance.			
(U)	In FY 2004: Expand investigations into the fundamental interplay between atoms and strong electromagnetic fields to identify potentially new classes of lasers. Continue measuring ultraviolet emission cross sections from electron impact. Explore uses for laser-cooled and trapped atoms. Note: In FY 2004, flash radiation efforts were transferred to another DoD agency.			
(U)	In FY 2005: Continue to characterize interactions of atoms and molecules in strong electromagnetic fields for laser			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2301 Physics**

	applications. Examine techniques for precision measurement of atomic and molecular properties, atomic collision processes, and fundamental interactions between atoms, molecules, ions, and radiation. Explore advances in high-resolution spectroscopy via the trapping and cooling of atoms and ions. Continue exploring dynamic molecular interactions in combustion and high energy density propellants. Continue examining materials, surfaces, and air breakdown in the presence of strong electric and sub-meter wave fields. Continue plasma physics studies in the areas of all-electric military platforms, high-bandwidth communications, and advanced long-distance covert surveillance. Continue probing the effects of short-pulse intense electric fields on cells and organelles. Note: In FY 2005, the "high-energy electro-energetics" efforts described earlier in this Project were moved to this activity.			
(U)				
(U)	MAJOR THRUST: Advance technologies for space sensors, imaging, identification, and tracking methods, and effective space situational awareness.	0.000	3.281	4.045
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Conduct research on the interaction of systems and sensors with atmospheric and space environments. Develop models to predict the atmospheric effects on laser propagation. Investigate means to expand models of sensor performance to incorporate measurements of terrestrial and space backgrounds and radiation. Examine methods of using holographic techniques for dynamic correction of distortion and aberration in space surveillance telescopes. Study methods to enhance hyperspectral imagery using polarization and hypertemporal information. Note: Highlighted focus area beginning in FY 2004.			
(U)	In FY 2005: Probe effects of atmospheric and space environments on sensors and energy (i.e., information) propagation. Identify, characterize, and model parameters enabling remote sensing, locating, and precision tracking of objects in and from space. Evaluate tools and enhance system interactions for enabling effective space situational awareness.			
(U)				
(U)	CONGRESSIONAL ADD: Center for Astronomical Active Optics.	1.923	0.992	0.000
(U)	In FY 2003: Expanded research studies on adaptive optics to further enable adaptive telescopes for laser beam projection into space, space reconnaissance, space power collectors, and space-based lasers.			
(U)	In FY 2004: Study optional methods and techniques that may be used to produce larger telescope based on ongoing adaptive optic accomplishments.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	CONGRESSIONAL ADD: National Fotonics Research Center.	0.000	1.686	0.000
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Support fundamental research at the National Fotonics Research Center.			
(U)	In FY 2005: Not Applicable.			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2301 Physics**

(U)				
(U)	CONGRESSIONAL ADD: Non-lethal Stunning/Immobilizing Weapons Research.	0.000	0.496	0.000
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Conduct fundamental scientific investigations in non-lethal stunning and immobilizing weapons research.			
(U)	In FY 2005: Not Applicable.			
(U)	Total Cost	23.487	25.749	23.690

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602203F, Aerospace Propulsion.									
(U) PE 0602204F, Aerospace Sensors.									
(U) PE 0602500F, Multi-Disciplinary Space Technology.									
(U) PE 0602601F, Space Technology.									
(U) PE 0602605F, Directed Energy Technology.									

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2302 Solid Mechanics and Structures	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2302 Solid Mechanics and Structures	11.236	11.641	13.276	14.873	16.594	17.314	18.535	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Solid mechanics and structures basic research aims to improve load-bearing performance of air and space structures through the prediction and control of multi-scale phenomena ranging from micro-level deformation and fracture of materials to the structural dynamics of large platforms. The goals are cost-effective development and safe, reliable operation of superior Air Force weapon and defensive systems. Fundamental knowledge of "multi-functional" structures with smart materials, sensors, actuators, and control systems integrated to accomplish damage control, thermal management, vibration reduction, and reconfigurable shapes. Research topics include: the modeling of non-linear static/dynamic behavior of structures; mechanical reliability of micro-devices; design of multi-functional materials; mechanical behavior of nano-materials; and composite materials for structures.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Explore advanced, nano-scale materials, mechanics, and devices for direct application in advanced turbine engines, air vehicles, space systems, and other weapon systems.	2.540	2.478	6.357
(U) In FY 2003: Conducted research in mechanics of advanced materials and devices to accelerate their use as composites, high-temperature alloys, and ceramic matrix composites. Applied multi-functional mechanics with nonlinear behavior to begin designing multi-functional materials and structures. Developed methods to combine multi-scale modeling and information technology to design new materials and structures.			
(U) In FY 2004: Enhance research in the mechanics of advanced materials and devices to accelerate their use as composites, high-temperature alloys, and ceramic matrix composites. Continue to apply multi-functional mechanics with nonlinear behavior to enhance design of multi-functional materials and structures. Continue development of methods to combine multi-scale modeling and information technology to design new materials and structures. Examine the foundations of nano-mechanics in transitioning between continuum mechanics and atomistic modeling.			
(U) In FY 2005: Advance research in the mechanics of materials and devices, with continued focus in the areas of multi-functional design, diagnostics, prognostics, self-healing, micro-/nano-mechanics, autonomics, thermal management, and energy harvest. Search for methods to combine information technology and multi-scale modeling in the design of new materials and structures. Continue nano-mechanics research to promote the transition from continuum mechanics to atomistic modeling. Note: In FY 2005, activities described later in this Project were moved to this activity.			
(U)			
(U) MAJOR THRUST: Analyze and model structural fatigue and loss of integrity to mitigate their detrimental impact to Air Force weapon systems.	4.506	4.965	0.000

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2302 Solid Mechanics and Structures**

(U) In FY 2003: Researched the structural and material aspects of high-cycle metal fatigue and other aging mechanisms of aircraft. Explored metal fatigue-generation caused by the vibration of compressor and turbine blades and blade motion/fluid flow coupling. Improved fundamental computer simulations to predict structural response to assorted stimuli. Investigated material science to identify and mitigate material degeneration and degradation. Advanced development of novel system techniques to analyze vehicle integrity.

(U) In FY 2004: Continue to investigate the structural and material aspects of high-cycle metal fatigue and other aging mechanisms. Continue to explore metal fatigue-generation caused by the vibration of compressor and turbine blades. Expand and enhance fundamental computer simulations to predict structural response to assorted stimuli. Explore material science research to identify and mitigate material degeneration and degradation. Continue to develop novel system techniques to analyze vehicle integrity.

(U) In FY 2005: Not Applicable. Note: In FY 2005, these efforts will be moved to the "structural fatigue and mechanics" activity in this Project.

(U)

(U) MAJOR THRUST: Conduct structural mechanics research to examine innovative adaptive structure concepts to improve the design and performance of air and space systems to include multi-mission unmanned aerial vehicles (UAVs).	4.190	4.198	0.000

(U) In FY 2003: Developed models to predict the interaction between structural motion and high-speed aerodynamics characteristic of UAVs. Further investigated the behavior of distributed sensor and actuator systems. Explored the mechanical and dynamic behavior of micro- and nano-scale structures to achieve exceptional capabilities in micro-electro-mechanical systems and nano-electro-mechanical systems.

(U) In FY 2004: Expand models to predict the interaction between structural motion and high-speed aerodynamics characteristic of UAVs. Further probe the behavior of distributed sensor and actuator systems of aircraft. Continue exploring the mechanical and dynamic behavior of micro- and nano-scale structures to achieve exceptional capabilities in micro-electro-mechanical systems and nano-electro-mechanical systems.

(U) In FY 2005: Not Applicable. Note: In FY 2005, these efforts will be moved to the "structural fatigue and mechanics" activity in this Project.

(U)

(U) MAJOR THRUST: Analyze structural fatigue and mechanics, adaptive structures, and material properties to improve the design, robustness, and performance of air and space systems to include multi-mission unmanned aerial vehicles (UAVs).	0.000	0.000	6.919

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Not Applicable.

(U) In FY 2005: Continue to examine and analyze structural mechanics to include fatigue, integrity, high cycle metal fatigue, and other material aging phenomena. Investigate metal fatigue-generation caused by the vibration of

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2302 Solid Mechanics and Structures**

compressors and turbine blades. Continue assessing means and models to identify, evaluate, and mitigate material degeneration and degradation. Continue developing novel system techniques to analyze vehicle integrity. Advance models of interaction between UAV structural motion and high-speed aerodynamics. Characterize distributed sensor and actuator systems. Explore the mechanical and dynamic behavior of micro/nano-scale structures. Note: Prior to FY 2005, these efforts were covered under other activities in this Project.

(U)	Total Cost	11.236	11.641	13.276

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602102F, Materials.									
(U) PE 0602201F, Aerospace Flight Dynamics.									
(U) PE 0602202F, Human Effectiveness Applied Research.									
(U) PE 0602203F, Aerospace Propulsion.									
(U) PE 0603211F, Aerospace Structures.									

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2303 Chemistry	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2303 Chemistry	27.987	27.939	29.292	28.531	31.485	28.218	28.698	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Chemistry basic research seeks bold innovations in understanding, modeling, and controlling chemical reactions for developing new materials, improving synthesis of existing materials, controlling energy flow and storage, and regulating interactions between materials and their environments. Studies expand fundamental understanding of properties regulating the chemical dynamics and energy transfer processes that foster advances in laser weaponry and allow predictions of the infrared, optical, and radar signatures of reaction products and intermediates that advance reliable target assessment and tracking. Critical research topics include: novel synthesis and characterization of lower cost, higher performance functional and structural materials, electronics, and photonic materials; nano-structures; electromagnetics; and conventional weaponry. Focused investigations include the effects of chemical and morphological structures on functional and mechanical properties of polymeric materials and the exploration of atomic and molecular surface interactions that limit performance of electronic devices, compact power sources, and lubricant materials. Primary areas of research include molecular reaction dynamics; theoretical chemistry; polymer chemistry; and surface and interfacial science.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Research and characterize molecular dynamics, reaction mechanics/interactions, and theoretical chemistry to model, predict, control, and exploit atomic and molecular energetics and reactivities for advanced fuels, munitions, and countermeasure techniques, as well as drag reduction.	10.776	11.654	13.523

(U) In FY 2003: Modeled interactions between aerospace systems and the space environment. Explored uses of ion and plasma chemistry for flow control applications. Investigated concepts of reactive energetic nano-structures for applications to propulsion and munitions. Developed and began to validate theoretical methods to predict and design behavior and properties of nano-structures. Modeled chemically reacting flows associated with hypersonic vehicles. Researched new chemical sources of electronic excited states needed to fuel chemical laser systems.

(U) In FY 2004: Complete modeling efforts of the chemical interactions between air and space systems and the space environment. Explore uses of ion and plasma chemistry for combustion control applications. Investigate concepts of reactive energetic nano-structures for safer penetrating munitions and enhanced spacecraft payload fractions. Develop and validate theoretical methods to predict and design the behavior and properties of nano-structures. Probe novel chemical theories, syntheses, detection techniques, and modeling and simulation focused on fuels and rocket propellants that are more energetic, environmentally benign, and emit reduced signatures and are less sensitive to accidental detonations. Study the fundamental behavior of new fuels in hydrocarbon-fueled scramjets and combined-cycle engines. Enhance models of chemically reacting flows associated with hypersonic vehicles. Research new chemical sources of electronic excited states needed to fuel chemical laser systems. Optimize properties of potential fuels to increase the mass of space payloads and satellite lifetimes.

Exhibit R-2a, RDT&E Project Justification			DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2303 Chemistry**	

(U) In FY 2005: Explore ion and plasma chemistry for combustion control applications. Investigate nano-structure concepts and models for propulsion and munition reactive energetics. Continue modeling chemically reacting flows associated with hypersonic vehicles, hydrocarbon-fueled scramjets, and combined-cycle engines. Continue to optimize chemical properties enriching high-energy lasers, advancing high-energy high-density fuels and materials, enhancing space lift, and extending time-on-orbit/station.			
(U)			
(U) MAJOR THRUST: Research super energetic propellants through chemical theory, synthesis, and detection techniques, as well as modeling and simulation focused on fuels and rocket propellants.	2.036	0.000	0.000
(U) In FY 2003: Studied the application of potential fuels for hydrocarbon-fueled scramjets and combined-cycle engines. Identified and investigated potential fuels increasing the mass of payloads put into space and increasing the lifetime of satellites on orbit.			
(U) In FY 2004: Not Applicable. Note: In FY 2004, these efforts were moved to the "molecular dynamics, reaction mechanics/interactions, and theoretical chemistry" activity in this Project.			
(U) In FY 2005: Not Applicable.			
(U)			
(U) MAJOR THRUST: Enhance fundamental understanding of polymer chemical structures, reactivity, molecular engineering, processing controls, and materials technologies to develop advanced organic and matrix composites aimed at improving Air Force systems performance and life-spans to allow effective air and space persistence.	9.273	9.286	8.737
(U) In FY 2003: Explored magnetic, conductive, and optical properties of coating materials to achieve smart skin concepts with on-demand tunable properties. Investigated bio-inspired polymer concepts to achieve enhanced photonic properties and photonic bandgap structures. Explored molecular conformational changes to achieve controllable mechanical actuation in polymeric materials. Exploited transportable large optics technology.			
(U) In FY 2004: Develop organic molecules with high optical nonlinearities for protection against laser threats. Explore flexible structures that can provide functions such as sensing, power generation and storage, electronics, and electronic memory for integration into multi-functional structures. Enhance electro-optic polymers for improved performance for photonic radar development. Research organic-based electronics for multi-functional integration.			
(U) In FY 2005: Design and characterize conductive polymers, photonic polymers, nano-structures, and bio-inspired polymers. Evaluate nano-composite structures and mechanical properties for potential applications under harsh space environments.			
(U)			
(U) MAJOR THRUST: Expand the fundamental chemistry and physics of surfaces and interfacial processes pertaining to corrosion protection, wear reduction, micro- and nano-assemblies, and power storage for air and space systems.	5.902	6.007	7.032
(U) In FY 2003: Developed theoretical and predictive methods for surface and interfacial chemical processes. Explored physical properties of novel lubricants to create new low-friction, long-life coatings and surface structures for			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2303 Chemistry**

terrestrial and space environments. Probed nano-scale surface structures with enhanced energy densities for better weapon system energy storage and delivery. Researched novel three-dimensional surface nano-structures for sensor, optical, and power applications.

(U) In FY 2004: Improve theoretical and predictive methods for surface and interfacial chemical processes. Explore the chemical and physical properties of novel lubricants. Assemble novel multi-functional coatings for the corrosion protection of aging aircraft. Develop low-friction, long-life multi-functional surface structures and coatings. Continue probing nano-scale surface structures with enhanced energy densities for better weapon system energy storage and delivery. Study chemically directed self-assembly to produce novel three-dimensional surface nano-structures for sensor, optical, and power applications.

(U) In FY 2005: Enhance theoretical and predictive methods for surface and interfacial chemical processes. Create and characterize novel multi-functional surface structures, coatings, covers, and lubricants. Continue investigating nano-scale surface structures for enhanced energy-density storage/delivery and chemically-directed self-assembled surfaces for sensor, optical, and power applications. Probe electro-chemical behaviors at surfaces and interfacial regions.

(U)

(U)	CONGRESSIONAL ADD: Corrosion Protection of Aluminum Alloys Used in Aircraft.	0.000	0.992	0.000
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Advance fundamental scientific research to enable, enhance, and exploit corrosion protection of aluminum alloys used in air and space vehicles.			
(U)	In FY 2005: Not Applicable.			
(U)	Total Cost	27.987	27.939	29.292

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602102F, Materials.									
(U) PE 0602203F, Aerospace Propulsion.									
(U) PE 0602500F, Multi-Disciplinary Space Technology.									
(U) PE 0602601F, Space Technology.									

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2303 Chemistry**

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

(U) PE 0602602F, Conventional Munitions.

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2304 Mathematical and Computer Sciences	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2304 Mathematical and Computer Sciences	31.286	29.293	25.663	34.397	39.314	35.952	32.022	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

Note: In FY 2005, some activities in this project will be moved to the Project 2311 in this Program Element.

(U) A. Mission Description and Budget Item Justification

Mathematics and computing sciences basic research develops novel techniques for mathematical modeling and simulation, algorithm development, complex systems control, and innovative analytical and high performance computing methods for air and space systems. Basic research provides fundamental knowledge enabling improved performance and control of systems and subsystems through accurate models and computational tools, artificial intelligence, and improved programming techniques and theories. The primary areas of research investigated by this project are dynamics and control; physical mathematics and applied analysis; optimization and discreet mathematics; computational mathematics; and electromagnetics.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Perform dynamics and control research to develop new techniques for design and analysis of control systems in order to enhance capabilities and performance of air and space vehicles.	6.172	6.488	7.735

(U) In FY 2003: Performed research on cooperative control in dynamic, uncertain, adversarial environments with applications to swarms of smart munitions, unmanned aerial vehicles (UAVs), and constellations of small satellites. Explored means to improve control of nonequilibrium behavior of complex, unsteady fluid systems (chemically reacting flows) with applications to combustion, and materials processing. Fostered advances in image processing and sensor technology that can be utilized in UAV controllers, smart munitions, and nondestructive vehicle testing. Commenced designing computational models to analyze natural processes for adaptation to air and space systems.

(U) In FY 2004: Continue research on cooperative control in dynamic, uncertain, adversarial environments with applications to swarms of smart munitions, UAVs, and constellations of small satellites. Develop control methodology to improve non-equilibrium behavior of complex, unsteady fluid systems (chemically reacting flows) with applications to combustion, materials processing, and agile autonomous flight. Explore advances in image processing and sensors applicable to advanced UAV controllers, smart munitions, and non-destructive vehicle testing. Enhance designs of computational models to analyze natural processes for adaptation to air and space systems. Adapt explorations in bio-inspired sensing systems to assess feasibility for and applicability in use in controlling autonomous systems.

(U) In FY 2005: Advance research on cooperative control in dynamic, uncertain, adversarial environments with applications to swarms of smart munitions, UAVs, and constellations of small satellites. Further develop control methodologies to improve non-equilibrium behavior of complex, unsteady fluid systems with applications for combustion, materials processing, and agile autonomous flight. Continue to probe advances in image processing and

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	sensor technologies for use in UAV controllers, smart munitions, and nondestructive vehicle testing. Investigate the adaptation of bio-inspired sensing systems, controls, and computational methods.			
(U)				
(U)	MAJOR THRUST: Investigate signal communications, surveillance, and targeting for increased awareness and improved command and control for the battlefield commander. Efforts include research in linear operator theory, generalized functions and probability, harmonic methods, and asymptotic expansions.	2.872	2.504	0.000
(U)	In FY 2003: Conducted investigations to expand the capability of critical mobile, networked communications, and surveillance/reconnaissance and targeting systems through examination of fundamental principles governing signal analysis. Explored source-channel encoding methods for robust wireless communication using optical transmission phenomenology. Developed a rigorous basis for and commenced delineating the domain of applicability of self-learning, trial and error (heuristic) methods such as super-resolution imaging. Researched technologies with higher information rates and higher reliability of communications.			
(U)	In FY 2004: Continue investigations to expand the capability of critical mobile, networked communications through mathematical innovations in signal processing. Explore hybrid radio frequency and optical phenomenology to achieve robust wireless communication. Further delineate the domain of applicability of self-learning and heuristic methods such as super-resolution imaging. Examine the fundamental principles of stochastic and probabilistic analysis to actuate proof-of-concept surveillance/reconnaissance and targeting systems. Examine revolutionary technologies that attain ultra-fast, reliable information exchange. Employ linear operator theory, generalized functions, differential equations, and quantum theory to facilitate flexible, high bandwidth reliable transmission of multi-source data.			
(U)	In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to Project 2311 in this Program Element.			
(U)				
(U)	MAJOR THRUST: Conduct research in complex systems and algorithms for highly flexible, reliable, and rich information systems supporting battlefield commanders; using artificial intelligence, information warfare, intelligent agents, knowledge bases, distributed systems, machine learning, uncertainty reasoning, and intelligence/ information assurance, and information fusion.	6.172	6.261	0.000
(U)	In FY 2003: Explored methods to enhance research in information operations, including support for language-based security, mobile code security, protected execution, and dynamic, adaptive intrusion detection for protection of future battlespace/infosphere systems and networks. Developed new computational techniques/software in extremely large (10,000,000+ axioms) knowledge bases to provide decision support.			
(U)	In FY 2004: Continue research in information assurance, including support for language-based security, mobile code security, protected execution, steganography/steganalysis, dynamic, and adaptive intrusion detection for protection of future battlespace/infosphere systems and networks. Further develop computational techniques/software for			

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information fusion at the situation refinement and impact assessment levels to provide decision support. Construct quantum computer devices that enable atomic level computing a million times faster than a state-of-the-art silicon chip to allow enhanced target tracking, command and control, and decisive awareness. Design, implement, and test quantum computing algorithms and architectures enabling fast, accurate solutions of complex fluid dynamics problems eliminating the need for multiple design iterations and prototype testing. Develop scalable quantum computers for automatic target recognition and target characterization.

(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to Project 2311 in this Program Element.

(U)

(U) MAJOR THRUST: Research physical mathematics, applied analysis, and electromagnetics.	6.613	6.216	8.257

(U) In FY 2003: Researched developing accurate models of physical phenomena to enhance the fidelity of simulations and predictability of devices. Investigated the properties of coherently propagating ultrashort laser pulses through the air and their exploitation in areas such as electronic warfare and laser-guided munitions. Developed algorithms to simulate nonlinear optical effects within semiconductor lasers and nonlinear optical media. Improved the formulation of optimal electromagnetic wave propagation/scattering codes to provide accurate and timely target recognition. Evaluated methods to penetrate tree cover with wide band radar to recognize and track targets. Studied the feasibility of designing reconfigurable warheads by suitable placement/timing of micro-detonators. Pursued the dynamics of internal stores released from transonic/supersonic platforms.

(U) In FY 2004: Continue research to develop accurate models of physical phenomena that enhance the fidelity of simulations and predictability of devices. Further investigate the properties of coherently propagating ultrashort laser pulses through the air and their exploitation in areas such as electronic warfare, laser-guided munitions, and irradiation of chemical/biological clouds. Develop algorithms to simulate nonlinear optical effects within fiber lasers and nonlinear optical media. Complete formulating optimal electromagnetic wave propagation/scattering codes to provide accurate and timely target recognition. Continue evaluating novel methods to penetrate tree cover with wide band radar to recognize and track targets. Continue studying the feasibility of designing reconfigurable warheads by suitable placement/timing of microdetonators. Enhance description of the dynamics of internal stores released from transonic/supersonic platforms.

(U) In FY 2005: Continue research to develop models of physical phenomena to improve simulations and device predictability. Investigate methods to advance target location, recognition and identification, and tracking. Probe the properties of coherently propagating ultra-short laser pulses through the atmosphere. Evaluate algorithms of nonlinear optical effects within fiber lasers and nonlinear optical media. Study the dynamics of transonic/supersonic/hypersonic platforms and warhead reconfiguration through micro-detonation.

(U)

(U) MAJOR THRUST: Investigate optimization and discrete mathematics to validate and further advance mathematical	4.897	4.382	0.000

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methods, algorithms, and models.

(U) In FY 2003: Conducted research for solving complex problems in logistics, engineering design, and strategic/tactical planning for battlespace information management. Evaluated anytime algorithms -- those that produce a feasible, but not necessarily optimal, solution. Examined new modeling techniques and algorithms for various Air Force problems such as target tracking, mobilization planning, and manufacturing.

(U) In FY 2004: Enhance research for solving complex problems in system diagnostics/prognostics, air mobility contingencies, and strategic/tactical planning for battlespace information management. Further evaluate anytime algorithms -- those that produce a feasible, but not necessarily optimal, solution. Continue examining new modeling techniques and algorithms for various Air Force current and long-term challenges, such as target allocation for unmanned air vehicles, special operations planning, and system health and maintenance.

(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to the "computational and discrete mathematics research" efforts in this Project.

(U)

(U) MAJOR THRUST: Perform computational mathematics research to develop unique modeling and simulation capabilities to improve designs of advanced Air Force systems.	4.560	3.442	0.000

(U) In FY 2003: Devised means to integrate new multi-disciplinary design optimization strategies with high-order, time-accurate solvers in order to design superior jet engines, aircraft wings, munitions, and other aerospace components. Developed new algorithms for unsteady reactive flow, munitions penetration and fragmentation, and plasma dynamics for directed energy weapons. Developed quantum computing algorithms, architectures, and implementations to enable exponential improvements in speed, accuracy, and fidelity of fluid dynamics simulations, signal processing, and data mining.

(U) In FY 2004: Initiate the integration of new multi-disciplinary design optimization strategies with high-order, time-accurate solvers for superior design of jet engines, aircraft wings, munitions, as well as other air and space components. Continue developing algorithms for unsteady reactive flow, munitions penetration and fragmentation, and plasma dynamics for directed energy weapons. Compute the simulation uncertainty in nonlinear models of aerodynamic flows and structural failure predictions.

(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to the "computational and discrete mathematics research" efforts in this Project.

(U)

(U) MAJOR THRUST: Conduct research in optimization, as well as computational and discrete mathematics to validate and further advance mathematical methods, algorithms, and modeling and simulation to solve problems and improve designs of advanced Air Force systems.	0.000	0.000	9.671

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Not Applicable.

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(U) In FY 2005: Solve complex problems in system diagnostics/prognostics, air mobility contingencies, and strategic/tactical planning for battlespace information management. Design modeling techniques and algorithms for various present day and longer term challenges. Integrate new multi-disciplinary design optimization strategies with high-order, time-accurate solutions for superior design of jet engines, directed energy devices, munitions and penetrators, air and space components, and system health and maintenance systems. Continue computing the simulation uncertainty in non-linear models of aerodynamic flows and structural failure predictions. Note: Prior to FY 2005, these activities were covered under other efforts earlier in this Project.

(U) Total Cost	31.286	29.293	25.663	

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602201F, Aerospace Flight Dynamics.									
(U) PE 0602203F, Aerospace Propulsion.									
(U) PE 0602500F, Multi-Disciplinary Space Technology.									
(U) PE 0602602F, Conventional Munitions.									
(U) PE 0602702F, Command, Control, and Communications.									
(U) PE 0603789F, C3I Advanced Development.									

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2305 Electronics	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2305 Electronics	23.234	25.041	25.174	26.833	29.722	29.674	30.117	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Electronics basic research enhances the fundamental understanding of electronic materials, devices, and systems to advance Air Force operational capabilities in directed energy weapons, stealth technologies, electronic countermeasures, information and signal processing, and communications. This research enables the development of electronic processes to model and predict the performance of electronic materials, devices, and systems for power generation, optical signal processing, radiation effects, and high-speed signal processing. The goals are to firmly control the complexity and reliability of electronic systems, increase data transmission and information processing speeds, and to improve the security and reliability of electronic information. The primary areas of research investigated by this project are space electronics: semiconductor materials; optoelectronic information processing and memory; and quantum electronic solids.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
	8.143	8.428	6.573

(U) MAJOR THRUST: Assess military space platform unique electronic circuits to increase their reliability, survivability, and functionality while simultaneously reducing component cost, size, and weight in order to improve spacelift, battlefield awareness and control, mission flexibility, and ease of augmentation and upgrade.

(U) In FY 2003: Expanded studies of intense radio frequency (RF) pulse effects on electronic circuits and systems. Commenced designing, fabricating, and evaluating wide bandgap semiconductor materials to achieve a unique combination of high RF power output, high efficiency, low noise, robustness, and radiation hardness. Examined reconfigurable electronics. Conducted research on the interaction of systems and sensors with the space environment. Developed models to predict the effect of terrestrial and space backgrounds and radiation on sensor performance in order to promote secure, wide-bandwidth communication through the atmosphere and ionosphere as well as between satellites. Initiated joint Air Force-NASA program in university nano-satellites, seeking novel space innovations and their demonstrations.

(U) In FY 2004: Probe intense RF pulse effects on electronic circuits and systems. Design, fabricate, and evaluate wide bandgap semiconductor materials to achieve a unique combination of high RF power output, high efficiency, low noise, robustness, and radiation hardness. Evaluate efforts to identify electronic approaches to increasing spacecraft survivability. Enhance research on the interaction of systems and sensors with the space environment. Continue development of models to predict the effect of terrestrial and space backgrounds and radiation on sensor performance in order to promote secure, wide-bandwidth communication through the atmosphere and ionosphere as well as between satellites. Explore design and potential applications of small satellites (1kg to 100 kg) for rapid access to space and flexible mission capabilities. Research scientific barriers to component miniaturization, nano-propulsion and power, smart skins, radiation hardening, and quantum effect electronics. Continue joint Air Force-NASA

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2305 Electronics**

	university nano-satellite projects with emphasis on space industry partnerships.			
(U)	In FY 2005: Further investigate effects of intense RF pulses on electronic circuits and systems. Continue designing, fabricating, and evaluating wide bandgap semiconductor materials towards achieve an unique combination of high RF power output, high efficiency, low noise, robustness, and radiation hardness. Research scientific barriers to electronic component miniaturization, nano-propulsion and power, smart skins, radiation hardening, and quantum effect electronics. Complete specific Air Force-NASA nano-satellite projects.			
(U)				
(U)	MAJOR THRUST: Conduct semiconductor materials research for detection and emission of optical radiation from the far infrared to ultraviolet range to achieve spectral dominance of the battlespace including surveillance, target tracking, and target signature identification.	7.127	7.580	0.000
(U)	In FY 2003: Investigated unique nonlinear optical materials to protect critical optical systems from laser radiation. Synthesized laser materials to degrade or disable an adversary's detection and tracking capabilities. Initiated development of nano-fabrication technology for unique optoelectronic material properties. Assessed basic electronic mechanisms to improve the efficiency and reduce the cooling requirements of lasers and detectors. Explored fast multi-band detectors for battlespace characterization.			
(U)	In FY 2004: Continue pursuit of nonlinear optical materials to protect critical optical systems from laser radiation. Synthesize laser materials to degrade or disable an adversary's detection and tracking capabilities. Enhance nano-fabrication technology for unique optoelectronic materials. Continue assessing basic electronic mechanisms to improve the efficiency and reduce the cooling requirements of lasers and detectors. Evaluate fast multi-band detectors for battlespace characterization. Identify new materials for high efficiency photovoltaic devices room temperature ferromagnets, and compact, high-power semiconductor lasers.			
(U)	In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to the "quantum and optoelectronic materials" efforts in this Project.			
(U)				
(U)	MAJOR THRUST: Conduct research in optoelectronic information processing and nano-science to explore the design, development, and application of novel optoelectronic materials and devices to enhance critical communication system accuracy and speed.	2.376	2.281	0.000
(U)	In FY 2003: Examined complex semiconductor structures and developed optical materials for use in high bandwidth, multi-wavelength modulators and detectors for satellite imaging and data transfer. Explored optoelectronic nanotechnologies including nano-photonics, nano-electronics, and nano-sensors and opportunities in terahertz technologies.			
(U)	In FY 2004: Continue exploration of ultracompact, micro-photonic, and nano-photonic structures and chip scale optical networks. Expand investigation of robust monolithic and miniature tetrahertz frequency devices for security, remote sensing, optical communications, and optical signal processing. Initiate terahertz quantum cascade laser			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
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	research.			
(U)	In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to the "quantum and optoelectronic materials" efforts in this Project.			
(U)				
(U)	MAJOR THRUST: Examine optoelectronic memory and persistent spectral hole-burning approaches for enhanced data storage and processing to enable superior strategic awareness.	1.587	1.522	0.000
(U)	In FY 2003: Investigated page-oriented or holographic memory configurations in two- or three-dimensions. Explored capabilities to buffer, store, and retrieve data at rates and quantities anticipated for multi-spectral devices. Developed new technologies to increase capabilities in high-speed image capture, data storage, and information processing for surveillance, target discrimination, and autonomous navigation. Advanced research on the interaction of systems and sensors with the space environment.			
(U)	In FY 2004: Continue investigating methods for constructing page-oriented or holographic memory configurations in two- or three-dimensions. Explore methods of buffering, storing, and retrieving data at rates and quantities anticipated for multi-spectral devices. Investigate techniques for enhancing capabilities in high-speed image capture, data storage, and information processing for surveillance, target discrimination, and autonomous navigation.			
(U)	In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to the "quantum and optoelectronic materials" efforts in this Project.			
(U)				
(U)	MAJOR THRUST: Investigate quantum and optoelectronic materials, memory, and information processing, as well as nano-science for wide-field spectral sensors and critical, high-speed communication systems in order to achieve spectral dominance of the battlespace to include surveillance, target tracking, and target signature identification.	0.000	0.000	13.545
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Not Applicable.			
(U)	In FY 2005: Continue exploring unique nonlinear optical and laser materials and fabrication processes for radiation protection, cloaking and tracking, and target signature identification. Improve efficiency and reduce cooling requirements of lasers and detector electronics. Explore ultracompact micro- and nano-photonic structures, chip-scale optical networks, and enhanced data storage (e.g., optoelectronic memory). Probe robust monolithic and miniature terahertz frequency spectrum devices and quantum cascade lasers. Investigate communication network technologies, room temperature ferromagnetic materials, and the interaction of system electronics and sensors with atmospheric and space environments. Note: Prior to FY 2005, these activities were covered under other efforts prior in this Project.			
(U)				
(U)	MAJOR THRUST: Investigate quantum electronic solids phenomena to explore superconducting, magnetic, and nanoscopic materials for advanced sensing, communications, and signal processing.	4.001	3.842	5.056
(U)	In FY 2003: Examined superconducting quantum systems for adaptation to quantum computing and encryption.			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
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Further investigated high-current, high-temperature superconducting cables and tapes for enhanced power generation and storage on Air Force directed energy weapons and space platforms. Developed new high-temperature magnetic materials with sufficient mechanical strength for use in aircraft with higher electric workloads.

(U) In FY 2004: Examine superconducting quantum systems for adaptation to quantum computing and encryption. Conduct research on improving high-current, high-temperature superconducting cables and tapes for enhanced power generation and storage on directed energy weapons and space platforms. Further the development of new high-temperature magnetic materials with sufficient mechanical strength for use in aircraft with higher electric workloads.

(U) In FY 2005: Continue examining superconducting quantum computing systems and encryption techniques. Examine methodologies to fabricate high current, high-temperature superconducting cables for enhanced power generation and storage devices. Continue the development of high-temperature magnetic materials with sufficient mechanical strength for use in aircraft electrical systems.

(U)

(U) CONGRESSIONAL ADD: Thin Film Magnetic Materials.	0.000	1.388	0.000	
(U) In FY 2003: Not Applicable.				
(U) In FY 2004: Study the fundamental scientific phenomena associated with thin film magnetic materials.				
(U) In FY 2005: Not Applicable.				
(U) Total Cost	23.234	25.041	25.174	

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602204F, Aerospace Sensors.									
(U) PE 0602702F, Command, Control, and Communications.									
(U) PE 0603203F, Advanced Aerospace Sensors.									
(U) PE 0603789F, C3I Advanced Development.									

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2306 Materials	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2306 Materials	14.170	15.035	15.917	15.971	17.704	17.538	17.871	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Materials basic research enhances the performance, cost, and reliability of structural materials to eliminate reliability issues related to high-temperature strength, toughness, fatigue, and environmental conditions. This research expands fundamental knowledge of material properties that leads to the development of novel materials for airframe, turbine engine, and spacecraft structures. The goals of this project are to develop improved materials for air and space vehicles that provide increased structural efficiency and reliability, increase the operating temperature of engine materials, and further increase thrust-to-weight ratio of engines. Basic research emphasis is on refractory alloys, intermetallics, polymer composites, metal and ceramic matrix composites, advanced ceramics, and new material processing methods. The primary areas investigated by this project are ceramics, non-metallic hybrid composites, and metallic materials.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Identify ceramic and non-metallic materials for use in developing new materials and composites for very-high (>1400F) and ultra-high (>2500F) temperature applications.	4.823	4.992	0.000
(U) In FY 2003: Investigated the optimization of thermal and mechanical stability of oxide composites for aircraft and jet engine blade applications. Created ultra-high temperature materials systems based on non-oxide materials for space applications. Worked toward designing and optimizing multi-functional materials to enable the combination of structural and functional ceramics to enable enhanced fuel cells, sensors, and actuators.			
(U) In FY 2004: Optimize the thermal and mechanical stability of oxide composites for aircraft and jet engine blade applications. Extend research on ultra-high temperature ceramic materials for space propulsion and structural systems. Maintain research focus on the design and optimization of multi-functional ceramic materials to enable structurally enhanced smart systems.			
(U) In FY 2005: Not Applicable. Note: In FY 2005, all non-metallic efforts will be combined into a single effort later in this Project.			
(U)			
(U) MAJOR THRUST: Investigate organic matrix composites and hybrid materials (including adhesives/epoxies) that can be used to increase the strength and life span of air and space structural materials.	2.291	2.270	0.000
(U) In FY 2003: Analyzed the effects of cyclic thermal loads on polymer matrix composites down to cryogenic temperatures to increase durability in liquid fuel tank materials. Developed new fiber sizing techniques in glass fiber reinforced structures to minimize degradation of mechanical and electromagnetic properties due to moisture.			
(U) In FY 2004: Further probe the effects of cyclic thermal loads down to cryogenic temperatures on polymer matrix composites in order to increase durability in liquid fuel tank materials. Continue research into fiber sizing techniques			

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in glass fiber reinforced structures to minimize the degradation of mechanical and electromagnetic properties due to moisture.			
(U) In FY 2005: Not Applicable. Note: In FY 2005, all non-metallic efforts will be combined into a single effort later in this Project.			
(U)			
(U) MAJOR THRUST: Perform non-metallic, ceramic, and hybrid materials research to identify and to design new materials and composites with s very-high (>1400F) and ultra-high (>2500F) temperature applications. Create organic matrix composites and hybrid materials (including adhesives/epoxies) used to increase the strength, application, and life span of air and space structural materials.	0.000	0.000	6.439
(U) In FY 2003: Not Applicable.			
(U) In FY 2004: Not Applicable.			
(U) In FY 2005: Optimize the thermal and mechanical stability of oxide composites for aircraft and engine applications. Identify and design multi-functional ceramic materials to enable structurally enhanced smart systems. Continue research on very-high and ultra-high temperature ceramic materials. Analyze cyclic thermal (cryogenic to high temperature) effects on organic and polymer matrix composites. Continue evaluating fiber-sizing techniques for glass/carbon fiber reinforced structures. Note: Prior to FY 2005, these activities were covered under other efforts earlier in this Project.			
(U)			
(U) MAJOR THRUST: Research metallic materials and identify relationships between structure (including microstructure), processing, properties and performance so as to develop affordable and durable metallic systems for advanced engines and aerospace structural applications.	7.056	7.773	9.478
(U) In FY 2003: Integrated computational modeling into the design of engineering components, the evaluation of the mechanical and thermal stability of metal matrix composites, and the characterization of refractory metal alloys and intermetallics in very-high temperature aircraft applications. Developed functionally graded structures for superior thermal barrier coatings. Created advanced metals for multi-functional space systems.			
(U) In FY 2004: Expand experimental and modeling studies of mechanical strength, thermal stability, performance prediction, and lifetime assessment of composites, refractory metal alloys, and intermetallics for applications at moderate and very high temperatures. Continue developing advanced alloys for multi-functional space systems. Explore scientific bases for computational design to reduce new material experimentation development costs. Develop new models to reduce new material maturity time and to minimize associated costs. Seek to develop high performance materials more affordably by integrating material development and engineering system design.			
(U) In FY 2005: Continue exploring and modeling metal matrix composites, refractory metal alloys, and intermetallics for applications at moderate and very high temperatures. Create advanced alloys for multi-functional space systems. Enhance and broaden computational models by implementing strategies that reduce new structural material maturity			

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time, assess/validate materials design codes, seek integration with design processes, and minimize costs.

(U)	Total Cost	14.170	15.035	15.917

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602102F, Materials.									
(U) PE 0602201F, Aerospace Flight Dynamics.									
(U) PE 0602203F, Aerospace Propulsion.									
(U) PE 0602500F, Multi-Disciplinary Space Technology.									
(U) PE 0602601F, Space Technology.									
(U) PE 0603211F, Aerospace Structures.									
(U) PE 0708011F, Industrial Preparedness.									

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2307 Fluid Mechanics	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2307 Fluid Mechanics	10.025	12.875	10.902	10.997	11.715	11.426	11.630	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Fluid mechanics basic research advances fundamental knowledge, tools, data, concepts, and methods for improving the efficiency, effectiveness, and reliability of air and space vehicles. The goals are to improve theoretical models for aerodynamic prediction and design, as well as to originate flow control concepts and predictive methods used to expand current flight performance boundaries through enhanced understanding of key fluid flow (primarily high-speed air) phenomena. Basic research emphasis is on turbulence prediction and control, unsteady and separated flows, subsonic/supersonic/hypersonic flows, and internal fluid dynamics. The primary approach is to formulate advanced computational methods to: simulate and study complex flows; predict real gas effects in high-speed flight; and control and predict turbulence in flight vehicles and propulsion systems. Primary areas of research investigated by this project are unsteady aerodynamics, supersonic and hypersonic aerodynamics, turbulence, as well as rotating and internal flow characteristics and controls.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Characterize the critical phenomena in unsteady aerodynamic flows and expand fundamental knowledge of high-speed airflows to optimize current air vehicle designs that will revolutionize future weapon systems.	2.521	2.760	0.000
(U) In FY 2003: Investigated unsteady, complex, three-dimensional flows to refine the control and flight performance of unmanned aerial vehicles (UAVs). Investigated rapid maneuver UAV aerodynamics. Investigated highly separated flow situations occurring in complex air vehicle and weapon systems.			
(U) In FY 2004: Develop numerical tools and validate the experimental database to determine the effect of unsteady, vortex-dominated flows on the control and flight performance of UAVs. Investigate aero/structure interactions associated with rapid maneuver UAVs. Evaluate tools for the accurate prediction of highly separated flow over complex air vehicle and weapon systems.			
(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will become part of the "supersonic, hypersonic, unsteady aerodynamics" efforts later in this Project.			
(U)			
(U) MAJOR THRUST: Investigate complex phenomena in supersonic and hypersonic flows to enable the design of future Air Force trans-atmospheric vehicles and flight control systems.	2.999	3.163	0.000
(U) In FY 2003: Developed supersonic flow control concepts, including plasma and magneto-hydrodynamic techniques. Developed high-speed flow prediction codes to quantify thermal stresses and designed mitigation techniques for hypersonic flight vehicles.			
(U) In FY 2004: Examine advanced flow control concepts for shock-dominated flows. Pursue aerothermal numerical			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004	
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2307 Fluid Mechanics**	

simulation capabilities to quantify heat transfer and unsteadiness for flight vehicles.

(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will become part of the "supersonic, hypersonic, unsteady aerodynamics" efforts later in this Project.

(U)

(U) MAJOR THRUST: Investigate and characterize complex phenomena in supersonic, hypersonic, and unsteady flows to enable and optimize the design of air and space vehicles and flight control systems.	0.000	0.000	4.912

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Not Applicable.

(U) In FY 2005: Explore methods to optimize unsteady, vortex-dominated flows and rapid maneuver control on unmanned aerial vehicles (UAVs). Model unsteady aerodynamics of complex, configuration-induced flows and characterize hypersonic flows to include boundary layer effects, engine integration, and plasma aerodynamics. Model aerothermal and local shock phenomena in hypersonic flows, control concepts, and performance optimization. Explore control strategies for the mitigation of excessive heat transfer and unsteadiness in hypersonic flows and for abating the effects of highly separated flows. Note: Prior to FY 2005, these activities were covered under other efforts earlier in this Project.

(U)

(U) MAJOR THRUST: Explore fundamental knowledge of turbulence in coordinated experimental and computational simulation efforts to enhance the performance, controllability, and stability in air vehicles.	2.521	2.760	0.000

(U) In FY 2003: Investigated new areas and methods of flow control on aircraft wings and jet engines. Developed reduced order models for turbulent flow control applications and affordable engineering predictive models for the air vehicle design process. Assessed quality of promising flow control actuation concepts on realistic geometries. Investigated flow control coupling mechanisms in turbulent flows to enable agile flight vehicles.

(U) In FY 2004: Develop approaches for modeling unsteady flow control inputs on aircraft wings and jet engines. Utilize reduced order models for turbulent flow control applications and affordable engineering predictive models for the air vehicle design process. Evaluate promising flow control actuation concepts on realistic geometries in wind tunnel tests. Further investigations into flow control-coupling mechanisms in turbulent flows to enable agile flight vehicles.

(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will become part of the "turbulence and rotating flows" efforts later in this Project.

(U)

(U) MAJOR THRUST: Study complex rotating and internal flow characteristics related to turbomachinery and jet engine applications.	1.984	2.209	0.000

(U) In FY 2003: Evaluated unsteady flow phenomena and enhanced the understanding of forcing modes in turbomachinery to predict and avoid high cycle and thermal failures in jet engines. Investigated application of large eddy simulation techniques to explore complex gas turbine engine flow fields and heat transfer effects. Evaluated

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
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flow control measurement and actuation devices for use in harsh environments.

(U) In FY 2004: Explore coupling mechanisms in multiple blade row interactions in order to develop understanding of forcing modes in turbomachinery and to predict high cycle fatigue failures in jet engines. Use large eddy simulation techniques to explore heat transfer and fluid flow coupling in turbine engine flow fields. Investigate detailed flow interactions using flow control measurement and actuation devices for use in harsh environments.

(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will become part of the "turbulence and rotating flows" efforts later in this Project.

(U)

(U) MAJOR THRUST: Expand fundamental knowledge of turbulence in coordinated experimental and computational simulation efforts. Study complex rotating and internal flow phenomena related to turbomachinery and jet engine applications.	0.000	0.000	5.990

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Not Applicable.

(U) In FY 2005: Evaluate validation studies of advanced flow control coupling mechanisms in turbulent flows. Use large eddy simulation techniques to probe heat transfer and fluid flow coupling. Model unsteady flow control inputs on wings and jet engines to include reduced order, closed-loop flow control demonstrations. Explore aerodynamic mistuning mechanisms in multiple blade row interactions tied to high cycle fatigue failures. Investigate detailed flow interactions using flow control measurements and actuation devices for harsh environments and wind tunnel tests. Note: Prior to FY 2005, these activities were covered under other efforts earlier in this Project.

(U)

(U) CONGRESSIONAL ADD: National Hypersonic Research Center.	0.000	1.983	0.000

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Conduct fundamental scientific and engineering research studies at the National Hypersonics Research Center.

(U) In FY 2005: Not Applicable.

(U) Total Cost	10.025	12.875	10.902

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost

(U) Related Activities:

(U) PE 0602102F, Materials.

(U) PE 0602201F, Aerospace Flight Dynamics.

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2307 Fluid Mechanics**

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

(U) PE 0602203F, Aerospace Propulsion.

(U) PE 0603211F, Aerospace Structures.

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2308 Propulsion	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2308 Propulsion	22.554	15.660	15.864	16.918	17.791	17.675	18.053	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Propulsion basic research expounds fundamental knowledge to enable and enhance efficient utilization of energy in airbreathing engines, chemical and non-chemical rockets, and combined cycle propulsion systems for future rapid global reach and on-demand space access. Basic research thrusts include airbreathing propulsion, space power and propulsion, high altitude signature characterization and contamination, propulsion diagnostics, thermal management of space-based power and propulsion, and the synthesis of new chemical propellants. These thrusts can be grouped into reacting flows and non-chemical energetics. Study of reacting flows involves the complex coupling between energy release through chemical reaction and the flow processes that transport chemical reactants, products, and energy. Non-chemical energetics research includes both plasma and beamed-energy propulsion for orbit raising space missions and ultra-high energy techniques for space-based energy utilization. Primary areas of research investigated by this project are space power, propulsion, combustion, and diagnostics.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Study methods for enabling and improving aerodynamics and propulsion for next generation air and space vehicles.	2.022	0.000	0.000
(U) In FY 2003: Expanded research studies to develop a sound scientific basis for plasma utilization to improve aerodynamic characteristics and propulsive efficiencies so as to enhance hypersonic vehicle range by more than 10%. Investigated plasma control effects and evaluated means to engineer them into operational systems. Investigated plasma effects on lowering fuel consumption, improving propulsion system performance, providing on-board power generation, and alleviating sonic boom and engine noise.			
(U) In FY 2004: Not Applicable. Note: In FY 2004, these activities will be consolidated with the "space propulsion and power" efforts in this Project.			
(U) In FY 2005: Not Applicable.			
(U)			
(U) MAJOR THRUST: Research and model space propulsion and power in the areas of chemistry, electronics, miniaturization, and contamination/signature.	6.915	6.700	7.923
(U) In FY 2003: Studied means to improve thrust and control of propulsion systems to develop high-precision constellations of cooperating micro-satellites. Expanded the understanding of mechanical-electric energy conversion to increase payload and thrust. Studied the feasibility of excess silicon as a space propellant in developing concepts for self-consuming satellites. Researched new engine concepts such as pulsed detonation engines, hybrid rockets, and combined cycle engines. Created advanced supercritical combustion models and leverage computational capability to enhance the design of new engines. Researched plasma turbulence and its effect on the transport coefficients to			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2308 Propulsion**

develop a new class of more versatile plasma thrusters.

(U) In FY 2004: Study micro-chemical, plasma-based, and beamed-energy based thrusters to improve thrust, specific impulse, and control of propulsion systems for high-precision constellations of cooperating micro-satellites in order to enhance decisive awareness of threats and opportunities. Further research into new engine concepts such as pulsed detonation engines, hybrid rockets, and combined cycle engines. Advance supercritical combustion models and leverage computational capabilities that will enhance the design of new hydrocarbon, cryogenic, and monopropellant-fueled engines. Complete research of plasma turbulence and its effects on the transport coefficients in order to develop a new class of more versatile plasma thrusters. Research high altitude signature characterization and spacecraft cross-contamination, especially in the presence of multiple thrusters and satellites. Examine magnetohydrodynamic (MHD) flow control to optimize propulsion system flow path performance in scramjets. Investigate lightweight super conducting magnet capability for onboard flight-rated systems needed to achieve MHD flow control of advanced engines. Investigate plasma ignition approaches to improve combustion efficiency and stability in scramjets and high altitude subsonic airbreathing propulsion systems.

(U) In FY 2005: Expand studies in plasma-based, charged droplet-based (collide), and beamed-energy thrusters. Explore new engine concepts such as pulsed detonation rocket engines. Evaluate unsteady flow coupling and plasma ignition combustion efficiencies and stability. Investigate high altitude signature characterization and spacecraft cross-contamination. Examine MHD flow control to optimize scramjet flow path performance. Investigate lightweight superconducting magnet capability for MHD flow control of advanced engines. Note: In FY 2005, the plasma activities in this effort will be moved to the "combustion, propulsion, and diagnostics" effort in this Project.

(U)

(U) MAJOR THRUST: Study diagnostics and data reduction analyses.	4.491	0.000	0.000

(U) In FY 2003: Completed studies of advanced diagnostics systems for data reduction and interpretation to create concepts for novel propulsion system applications. Completed study of laser-induced fluorescence and absorption spectroscopic measurements in relation to infrared and ultraviolet excitation wavelength regimes.

(U) In FY 2004: Not Applicable. Note: In FY 2004, these activities will be consolidated with "combustion and diagnostics" efforts in this Project.

(U) In FY 2005: Not Applicable.

(U)

(U) MAJOR THRUST: Explore combustion, propulsion, and diagnostics in subsonics, supersonics, and hypersonics.	6.626	6.432	7.941

Investigate multi-phase, turbulent reacting flows to improve the performance of propulsion systems, including gas turbines, ramjets, scramjets, pulsed detonation engines, and rockets.

(U) In FY 2003: Developed enhanced computer models that predict unsteady behavior, such as combustion instability. Advanced the state of large eddy simulation methods for turbulent hydrocarbon combustion by incorporating upgraded subgrid-scale models for chemistry and fuel droplets.

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2308 Propulsion**

(U) In FY 2004: Improve laser diagnostic measurement capabilities with expanded agility over limited wavelength ranges for time-resolved characterization of reacting flows. Develop detailed mechanisms for hydrocarbon fuel combustion at elevated pressures. Explore scientific basis for how plasmas are used to improve aerodynamic characteristics and propulsive efficiencies.

(U) In FY 2005: Improve laser diagnostic measurement capabilities in the characterization of reacting flows. Probe molecular transport effects causing and enhancing thermal destabilization of hydrocarbon fuels under supercritical thermodynamic conditions. Incorporate prediction methodologies, which are both quantitatively accurate and computationally tractable, into turbulent combustion models. Enhance scientific bases for how plasmas are used to improve aerodynamic characteristics and propulsive efficiencies. Identify and evaluate fuels and propellants that are more energetic, environmentally benign, and less sensitive to accidental detonations.

(U)

(U) CONGRESSIONAL ADD: Coal-derived Jet Fuels.	2.500	2.528	0.000
(U) In FY 2003: Produced limited quantities (50 gallons) of coal-derived fuel for large-scale combustion, fuel system fouling, and ignition experiments. Furthered investigations for coal-derived fuel production scale-up.			
(U) In FY 2004: Produce coal-based jet fuels in increasingly larger quantities through refinery trials. Evaluate refinery produced fuels for large-scale combustion and thermal stability.			
(U) In FY 2005: Not Applicable.			
(U) Total Cost	22.554	15.660	15.864

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602102F, Materials.									
(U) PE 0602203F, Aerospace Propulsion.									
(U) PE 0602500F, Multi-Disciplinary Space Technology.									
(U) PE 0602601F, Space Technology.									
(U) PE 0603211F, Aerospace Structures.									

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2308 Propulsion**

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2311 Space and Information Sciences	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2311 Space and Information Sciences	14.681	20.379	24.661	23.286	22.523	22.868	23.660	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

Note: In FY 2005, the Project name, "Space Sciences," changed to "Space and Information Sciences." Additionally, in FY 2005, some activities in Project 2304 of this Program Element will be moved to this Project.

(U) A. Mission Description and Budget Item Justification

Space and information sciences basic research provides fundamental understanding of the space environment for optimum design of Air Force systems operating in near-Earth orbit, geosynchronous orbit, and deep space. The goal is to enable greater, more cost-affordable, protection of space assets from space debris, solar wind, solar flares, cosmic rays, and geomagnetic storms. Focus is on specifying the flow of mass, momentum, and energy through space to develop a global model that connects solar activity with the deposition of energy at the Earth. Methods are developed to forecast the turbulent plasma phenomena that mediate the flow of energy through space in order to enhance the effectiveness of Air Force global dominance through space operations. The primary areas of research investigated by the space environment portion of this program are solar phenomena and weather; magnetospheric and ionospheric effects; space debris studies; and innovative space-based communications. The primary research areas in the information sciences portion of this program are complex systems and algorithms, communications and signal processing, information operations, and information fusion.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Analyze solar physics and weather to develop techniques for improved space observations and protection of Air Force space assets and operations.	3.714	3.628	0.000

(U) In FY 2003: Observed and analyzed solar phenomena to characterize and model the physics of solar magnetic fields for enhanced prediction of large-scale, high-energy plasma ejections to develop protective spacecraft structures and more robust designs. Explored technology requirements to enable development of a new ground-based Advanced Technology Solar Telescope to exploit adaptive optics techniques. Expanded the investigation of solar dynamo physics, solar oscillation modes, solar flares, coronal mass ejections, magnetic reconnection in space plasmas, and solar magnetic field complexity to enable forecasting of solar eruptions and predict environmental risks to critical Air Force space operations.

(U) In FY 2004: Exploit solar physics models to develop techniques for protecting assets against high-energy plasma ejections. Support cutting-edge instrumentation development for the ground-based Advanced Technology Solar Telescope. Continue investigating solar flares, coronal mass ejections, magnetic reconnection in space plasmas, and solar magnetic field complexity through support of ground-based optical and radio solar observatories, as well as university and government teams managing space-based instruments. Define best practices and commonalities of algorithms used to model and simulate the space environment, focused on plug-and-play capability within next-generation computational architectures.

Exhibit R-2a, RDT&E Project Justification			DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2311 Space and Information Sciences**	

(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will be consolidated into "Space Environment Research" efforts later in this Project.			
(U)			
(U) MAJOR THRUST: Research magnetosphere and ionosphere effects to enhance global surveillance, geolocation, and communication.	3.714	3.628	0.000
(U) In FY 2003: Developed mitigation techniques for ionospheric scintillation and plasma turbulence radio disruptions to enhance global surveillance, geolocation, and communication. Supported scientific analysis of space-based and ground-based data assimilation techniques to modernize ionospheric and space weather forecasting. Observed atmospheric gravity wave interactions from high and low geomagnetic latitudes, as well as tropical observation sites, using radars, advanced electro-optical instrumentation, and light detection and ranging techniques in order to develop seasonal and climatic models of ionospheric phenomena.			
(U) In FY 2004: Expand deployment of research sensors to observe ionospheric scintillation and worldwide plasma turbulence radio disruptions. Support scientific analyses of space-based and ground-based data assimilation techniques to modernize ionospheric and space weather forecasting. Design and examine observational equipment globally to improve capability to observe atmospheric gravity wave interactions with radars, advance electro-optical instrumentation, and light detection and ranging techniques. Exploit cutting-edge developments in all-sky imaging optics to obtain sensitive infrared observations of ionospheric plasma physics, gravity waves, dynamics, and optical clutter.			
(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will be consolidated into "Space Environment Research" efforts later in this Project.			
(U)			
(U) MAJOR THRUST: Research, characterize, and model space debris to protect Air Force space assets.	4.215	4.310	0.000
(U) In FY 2003: Improved the cataloging and tracking the populations of Near Earth Objects (NEOs) and space debris particles derived from comets and asteroids. Explored laser guide-star development for observations of NEOs, as well as ballistic and orbital targets. Developed advanced astronomical instrumentation and observational methods to include laser ranging and adaptive optics for deep space surveillance. Began studies into the developments in astronomical detection and tracking algorithms for enhancement of DoD surveillance capabilities, and support observational campaigns to characterize the aerodynamic drag, turbulence, and optical clutter in the lower ionosphere that degrade DoD targeting.			
(U) In FY 2004: Continue efforts to catalog and track the populations of Near Space/Earth Objects and space debris particles derived from comets and asteroids. Advance multi-conjugate adaptive optics for unparalleled resolution of small, dim, deep space targets. Further developments in astronomical detection and tracking algorithms to enhance space awareness and control capabilities. Expand development of future space radar surveillance systems using nanotechnology and advanced signal processing algorithms.			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2311 Space and Information Sciences**

(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will be consolidated into "Space Environment Research" efforts later in this Project.			
(U)			
(U) MAJOR THRUST: Expand theories for the development of physics-based modeling, improved space observations through advancements in multi-conjugate adaptive optics, and the quantifying of risks to Air Force systems.	3.038	2.954	0.000
(U) In FY 2003: Provided support to the Air Force's Communications/Navigation Outage Forecast System and Solar Mass Ejection Imager satellite missions. Investigated the theoretical underpinnings of robust antenna designs for the space environment and charged particle remediation techniques. Investigated the variable energy deposited in near-Earth space by energetic charged particles from deep space and by cosmic rays to quantify risks to Air Force systems.			
(U) In FY 2004: Create new space environment models and enhance current theories using data from the Air Force's Communications/Navigation Outage Forecasting System and Solar Mass Ejection Imager satellite missions. Continue investigating the theoretical underpinnings of active and passive space environment remediation techniques. Stimulate novel efforts to advance design, study, and development new sensor technologies to observe cosmic rays and energetic charged particles from deep space in order to better quantify risks to Air Force systems. Research simulation and visualization techniques to simplify complex data analysis and ensure future strategic awareness.			
(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will be consolidated into "Space Environment Research" efforts later in this Project.			
(U)			
(U) MAJOR THRUST: Research space environment to improve solar theories and modeling in the areas of solar phenomena and weather, magneto/ionosphere effects, space debris, adaptive optics for improved space observation, better space-based communications, and the quantifying of risks to space systems.	0.000	0.000	8.463
(U) In FY 2003: Not Applicable.			
(U) In FY 2004: Not Applicable.			
(U) In FY 2005: Exploit astronomical detection, tracking, and cataloging algorithms for enhanced protection of DoD surveillance capability in conjunction with data from the Communications/Navigation Outage Forecasting System and Solar Mass Ejection Imager satellites. Support development of ground-based advanced technology solar telescope adaptive optics systems, light detection and ranging radars, nanotechnology, and advanced signal-processing algorithms. Refine forecasting of ionosphere and space environment effects. Exploit developments in all-sky imaging and multiconjugate adaptive optics to obtain infrared observations of ionospheric plasma physics, gravity waves, dynamics, optical clutter and small, dim, deep space targets. Continue investigating solar flares, coronal mass ejections, magnetic reconnection in space plasmas, and solar magnetic field complexity. Note: Prior to FY 2005, these activities were part of other efforts earlier in this Project.			
(U)			
(U) MAJOR THRUST: Investigate innovative technologies for space-based communication capabilities to ensure	0.000	1.000	1.000

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2311 Space and Information Sciences**

continued Air Force space dominance.

(U) In FY 2003: Not Applicable. Note: This is a new thrust area for FY 2004.

(U) In FY 2004: Research innovative methods for optical communications. Begin probing novel techniques for potential bandwidth efficient modulation to enhance satellite communications. Start exploring the basic mechanisms of dual polarization antennas for space applications.

(U) In FY 2005: Examine innovative methods for optical communications. Probe novel techniques for potential bandwidth efficient modulation to enhance satellite communications. Explore the basic mechanisms of dual polarization antennas for space applications.

(U)

(U) MAJOR THRUST: Investigate signal communications, surveillance, and targeting for increased awareness and improved command and control for the battlefield commander. Efforts include research in linear operator theory, generalized functions and probability, harmonic methods, and asymptotic expansions. Note: Prior to FY 2005, these activities were covered under Project 2304 in this Program Element.	0.000	0.000	4.211

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Not Applicable.

(U) In FY 2005: Improve data fusion science to permit rapid data conversion across multiple bands into graphical and conceptualized information. Promote methodologies to evaluate the performance of new wireless mobile, networked communications systems. Assess technical alternatives on the overall feasibility of super-resolution millimeter and search and rescue imagery. Solidify the hybrid radio-frequency/free-space optical paradigm and refine the parameters of other innovative technologies to attain ultra-fast, reliable information exchange. Enable ultra-wide band transmission of hyperspectral and other diverse data.

(U)

(U) MAJOR THRUST: Conduct research in complex systems and algorithms for highly flexible, reliable, and rich information systems supporting battlefield commanders using artificial intelligence, information warfare, intelligent agents, knowledge bases, distributed systems, machine learning, uncertainty reasoning, and artificial intelligence, information assurance, and information fusion. Note: Prior to FY 2005, these activities were covered under Project 2304 in this Program Element.	0.000	0.000	10.987

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Not Applicable.

(U) In FY 2005: Continue research in information assurance for protection of future battlespace/infosphere systems and networks. Develop information fusion to provide deep, adaptive, expert decision support. Construct quantum computer devices and algorithms to allow enhanced tracking, recognition, and characterization to improve awareness, command and control. Design, implement, and evaluate quantum-computing architectures for fast, accurate solutions of complex fluid dynamics.

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2311 Space and Information Sciences**

(U)				
(U)	CONGRESSIONAL ADD: Chabot Space and Science Center.	0.000	1.983	0.000
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Support the development of astronomical and scientific research and education capabilities at the Chabot Space and Science Center.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	CONGRESSIONAL ADD: Quantum Information Technology.	0.000	1.091	0.000
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Conduct fundamental scientific research associated with quantum information technologies.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	CONGRESSIONAL ADD: Information Security and Cyber Counter Terrorism.	0.000	1.785	0.000
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Conduct fundamental scientific studies related to information security and cyber counter terrorism.			
(U)	In FY 2005: Not Applicable.			
(U)	Total Cost	14.681	20.379	24.661

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities: PE 0602500F, Multi-Disciplinary Space Technology.									
(U) PE 0602601F, Space Technology.									
(U) PE 0602702F, Command, Control, and Communications.									
(U) PE 0603410F, Space System Environmental Interactions Technology.									
(U) PE 0603500F, Multi-Disciplinary Advanced									

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY 01 Basic Research	PE NUMBER AND TITLE 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE 2311 Space and Information Sciences

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

Development Space
Technology.

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2312 Biological Sciences	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2312 Biological Sciences	13.605	9.272	9.631	9.756	13.443	10.279	10.526	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Biological basic science research provides the fundamental knowledge necessary to understand and enable technologies associated with chemical and physical agent toxicity, electromagnetic sensors based on biomimicry, biomolecular materials, biochromatics, and luminescence. The goal is to exploit biological properties to control and manipulate operational environments. Research topics in toxicology explore the interaction of Air Force chemicals and physical agents (lasers and microwaves) with human tissues and associated effects to enable safety assessment strategies to ensure the hazard-free development and use of future air and space materials and directed energy systems. Research in biomimetic sensors strives to mimic the biological detection systems of organisms at the molecular level in developing novel man-made sensors. Basic research in biocatalysis characterizes cellular enzymes that will catalyze the synthesis of chemical feedstocks used in the safe production of space and air materials. Research in biomaterials focuses on the mimicking of natural materials, using organisms as biomaterial factories of new materials, genetically altering existing organisms for new materials capabilities, or taking existing biomaterials/organisms and using them as novel materials like viral gradients or processing them further to make a useful material as in biominerialization. Research in biointerfacial science is focused on new biosensors and bionanotechnology, and specifically addresses the fundamental science at either the biotic-biotic or the biotic-abiotic interface. The primary areas of research investigated by this project are bio-informatics, profiling, and response; biocatalysis and bioenzymatic properties; and biomimetic, biomaterials, and biointerfacial sciences.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Investigate natural response profiling and assessment from exposure to fuels, chemicals, and directed energy systems. Probe biocatalysis and bioenzymatic properties to characterize and modify enzymes as affordable and efficient catalysts in the manufacture of air and space materials.	6.136	6.912	5.568

(U) In FY 2003: Identified organ-specific molecular pathways altered by JP-8 jet fuel exposures and evaluated various biomolecular indicators and mediators of the toxic response for use as potential biomarkers of human exposure and to enable the development of protective strategies. Explored mechanisms and commenced developing novel molecular descriptors that will help integrate in vitro toxicity data into a mathematical format for use in the rapid computational prediction of toxicity of air and space chemicals and new forms of directed energies. Investigated the biological effects of chronic low-level exposures to directed energy by profiling and modeling intracellular molecular responses and commenced identifying potentially harmful extra-cellular mediators.

(U) In FY 2004: Continue a biokinetics study of the uptake, biodistribution, metabolism, and elimination of JP-8 fuel in animals exposed through the inhalation and skin routes as a first step in assessing the risks of jet fuels. Extend research on molecular descriptors and mathematical expression of in vitro toxicity data to include data from genomics and proteomics profiles to rapidly predict computationally the toxicity of air and space chemicals. Extend sensitive genomics and proteomics profiling techniques to studies investigating the cellular and extra cellular effects of chronic

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2312 Biological Sciences**

	and acute low-level exposures of animals to laser and microwave systems. Note: In FY 2004, the "biocatalysis and bioenzymatic" activities were moved from another effort later in this Project to this effort.			
(U)	In FY 2005: Model risks associated with exposure to fuels and complex mixtures. Analyze the biokinetics and biodistribution of JP-8 jet fuel components. Continue exploring, profiling, and modeling bio-informatics methodologies. Characterize, parameterize, and codify enzymes, proteins, biocatalysts, and bio-energetic agents to enable and enhance efficiencies in the synthesis and processing of future air and space materials.			
(U)				
(U)	MAJOR THRUST: Evaluate biocatalysis and bioenzymatic properties to characterize, modify, and utilize enzymes as catalysts in the processing and manufacturing of air and space materials.	3.661	0.000	0.000
(U)	In FY 2003: Furthered the essential and fundamental process of enzyme discovery and characterization. Genetically modified the natural biocatalytic potential of enzymes to meet various synthetic manufacturing requirements by extending substrate ranges and specificities or altering reaction rates. Explored alternative metabolic engineering techniques for maintaining or enhancing reaction rates during large-scale production.			
(U)	In FY 2004: Not Applicable. Note: In FY 2004, these activities were consolidated into the "bio-response profiling and assessment" efforts earlier in this Project.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	MAJOR THRUST: Model chronobiology (biophysical and neural) mechanisms to determine a warfighter's cognitive performance under conditions of sleep loss, sustained operations, and non-standard sleep/wake duty cycles.	2.051	0.000	0.000
(U)	In FY 2003: Investigated the biophysical mechanisms responsible for crew fatigue in sustained operations or in non-standard duty cycles and in adapting to jet lag. Explored mathematical models of sleep/wake dynamics, including the effects of wake-promoting countermeasures on the homeostatic and circadian systems, and extended these models to predict specific deficits in human performance under conditions of sleep loss. Conducted new research to identify the phenotypic differences that enable some individuals to maintain highly accurate cognitive and psychmotor performance under sleep deprivation. Note: In FY 2003, the vast majority of these efforts were in this activity were completed, so this separate focus was closed.			
(U)	In FY 2004: Not Applicable.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	MAJOR THRUST: Explore biomimetics, biomaterials, and biointerfacial sciences to enable development of novel sensors, engineering processes and mechanisms, and the synthesis of novel materials.	1.757	2.360	4.063
(U)	In FY 2003: Enhanced modeling of the fundamental principles, processes, and designs of infrared sensitive biosystems at the sub-cellular, molecular and genomic levels to enable the further development of infrared materials, devices, and systems with enhanced structural and functional capabilities. Identified, modeled, and constructed			

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alternative biomimetic, near ambient infrared sensing devices. Probed and manipulated the functionality of alternative sensors for time-response characteristics. Commenced adapting biochromophores and biophotoluminescent characteristics in microbial and protein-based biosystems for applications to military sensor systems.

(U) In FY 2004: Model the fundamental principles, processes, and designs of non-cryogenic infrared sensitive biosystems at the sub-cellular and molecular levels to enable future infrared materials, devices, and systems with enhanced structural and functional capabilities to identify, model, and construct near ambient infrared sensing devices. Continue adapting characteristics of microbial and protein-based biosystems for applications to military sensor systems. Explore mimicking natural materials, using organisms as factories of new materials, or taking existing biomaterials and processing them into Air Force useful materials. Study the fundamental science and nano surface structure of biomaterials for application to military sensor systems that will ensure reliable assessment and monitoring.

(U) In FY 2005: Investigate, evaluate, and model natural occurrences, processes, and designs for future applications in infrared devices. Explore biochromophores and biophotoluminescent characteristics in microbial and protein-based biosystems for applications to military sensor systems. Exploit biomaterial and biointerfacial sciences to synthesize novel materials, evaluate biosensors, and elucidate bionanotechnology applications.

(U) Total Cost	13.605	9.272	9.631

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602202F, Human Effectiveness Applied Research.									
(U) PE 0602204F, Aerospace Sensors.									
(U) PE 0602602F, Conventional Munitions.									
(U) PE 0602702F, Command, Control, and Communication.									

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 2313 Human Performance	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
2313 Human Performance	12.332	12.667	13.596	13.655	14.412	14.105	14.319	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

Human performance basic research provides the fundamental knowledge necessary to examine and exploit all aspects of human information processing critical to Air Force operations. The goal is to develop useful quantitative models of the way warfighters perceive, appraise, and manipulate their environment; make decisions in complex tasks under stress or uncertainty; and adapt to extreme sensory, biophysical, or cognitive workloads. Sensory research emphasizes visual, auditory, equilibrium, and kinesthetic systems and their optimal integration. Basic research topics focus investigations on the scientific foundation for several developing Air Force technologies including specialized interactive displays, simulators, intelligent control systems, sensors and fused-image displays, and adaptive systems for operator and team training. Novel strategies to maintain decisive awareness by preventing impaired operating performance due to jet lag, shift work, night operations, and the loss of life and/or aircraft due to stress, inattention, or lack of vigilance are being evaluated. The primary areas of research investigated by this project are sensory systems; cognition, perception, and chronobiology; and behavioral and physiological measures of fatigue.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Probe human sensory systems and perceptions critical for warfighter performance (auditory and visual processes, multi-sensory integration, and sensory biomimetics) to enhance human-machine interaction in Air Force weapon systems. Research biophysical and neural mechanisms to determine human cognitive performance under conditions of sleep loss, sustained operations, and non-standard sleep/wake duty cycles.	3.363	3.468	7.856

(U) In FY 2003: Tested theories of sensory and perceptual systems. Evaluated theories and models of perception and cognition for accurate simulation and fused sensor processing. Investigated novel methods for evaluating design options for visual displays used in scene analysis and command and control in several task domains. Used performance metrics to critically test theories of sensory integration for image understanding.

(U) In FY 2004: Critically investigate and model theories of sensory and perceptual systems. Continue evaluating theories and models of perception and cognition for more accurate simulation and improved fusion of sensor data. Examine visual information processing techniques to improve methods for evaluating display designs, enhancing the capability for collaboration, and improving the movement and sharing of information. Use performance metrics to critically test theories of sensory integration to understand complex images. Probe intrinsic differences in humans that make some individuals highly resistant to, and other highly susceptible to, sleep loss.

(U) In FY 2005: Conduct empirical research with mathematical and/or computational modeling in spatial audition, speech perception, and hearing protection. Assess multi-sensory integration methods and novel biological sensing mechanisms. Probe biophysical mechanisms responsible for fatigue. Evaluate models of sleep/wake dynamics to predict specific deficits in warfighter performance.

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2313 Human Performance**

(U)				
(U)	MAJOR THRUST: Evaluate cognition and perception research to measure and analyze dimensions of human performance in complex, multi-interaction command and control tasks. Investigate behavioral and physiological theories of cognitive workload, alertness, and vulnerability to sleep loss.	4.648	4.704	5.740
(U)	In FY 2003: Extended models of cognitive dimensions of human performance in complex command and control tasks to inform studies of automated decision-making. Tested models of enhanced human performance aided or augmented by intelligent systems. Commenced determining mechanisms affecting training effectiveness for operator and team performance under stress and sustained operations.			
(U)	In FY 2004: Extend models of the cognitive dimensions of human performance in complex command and control tasks to enable studies of automated decision-making and enhanced risk assessment and measured response. Continue testing models for enhanced human performance aided or augmented by intelligent systems. Explore mechanisms affecting training effectiveness of operator and team performance under stress and sustained operations.			
(U)	In FY 2005: Analyze models of enhanced human performance aided or augmented by intelligent systems. Assess mechanisms affecting training effectiveness for operator and team performance. Continue modeling relationships between individual skill differences and interactions with envisioned training. Explore measures to avert/mitigate human error in conditions of information overload and fatigue.			
(U)				
(U)	MAJOR THRUST: Study and critically test behavioral and physiological theories of cognitive workload, alertness, and vulnerability to sleep loss in several domains of operator performance.	4.321	4.495	0.000
(U)	In FY 2003: Improved modeling relationships between individual skill differences and interactions with envisioned training pedagogies. Further determined behavioral and physiological measures to avert human error in conditions of information overload and fatigue.			
(U)	In FY 2004: Model relationships between individual skill differences and interactions with envisioned training techniques. Study behavioral and physiological measures to avert human error in conditions of information overload and fatigue and maintain full spectrum air and space vigilance.			
(U)	In FY 2005: Not Applicable. Note: In FY 2005, these activities will be consolidated into the "cognition and perception" efforts earlier in this Project.			
(U)	Total Cost	12.332	12.667	13.596

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0602202F, Human									

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **2313 Human Performance**

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

(U) Effectiveness Applied Research.
PE 0602702F, Command,
Control, and Communication.

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 01 Basic Research	PE NUMBER AND TITLE: 0601102F Defense Research Sciences	PROJECT NUMBER AND TITLE: 4113 External Research Programs Interface	

Cost ($ in Millions)	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total
4113 External Research Programs Interface	6.962	7.346	9.638	11.415	13.769	15.749	17.907	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

External basic research programs interface facilitates interactions between the international and domestic research communities and U.S. Air Force researchers. These professional interchanges and collaborations stimulate scientific and engineering education beneficial to the Air Force, increase the awareness of Air Force basic research priorities, and attract talented scientists and engineers to address Air Force needs. International interactions ensure future interoperability of coalition systems and foster relationships with future coalition partners. Projects also seek to enhance educational interactions with historically black colleges and universities, Hispanic serving institutions, and minority institutions. The primary elements of this effort are international strategy, international technology liaison, and scientist and engineer research interchange.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Support the Air Force Research Laboratory international strategy mission.	2.303	2.458	0.000
(U) In FY 2003: Provided centralized international expertise to assist formulation of optimal cooperation with, and leveraging of, foreign science programs to the benefit of the Air Force. Provided the primary interface with the Office of the Secretary of Defense, the Office of the Secretary of the Air Force, and the Air Force Materiel Command to coordinate international participation among appropriate U.S. Department of Defense organizations.			
(U) In FY 2004: Continue provide centralized international expertise to assist formulation of optimal cooperation with, and leveraging of, foreign science programs to the benefit of the Air Force. Provide the primary interface with the Office of the Secretary of Defense, the Office of the Secretary of the Air Force, and the Air Force Materiel Command to coordinate international participation among appropriate Department of Defense organizations.			
(U) In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to the "international science and technology" efforts later in this Project.			
(U)			
(U) MAJOR THRUST: Support the international technology liaison missions, through the European Office of Aerospace Research and Development and the Asian Office of Aerospace Research and Development, to identify unique international research capabilities and make them available to the Air Force.	2.732	2.803	0.000
(U) In FY 2003: Supported on-site coordination with international research organizations and support international visits of high-level DoD delegations. Sustained and funded Air Force commitment to NATO-affiliated research institutes, such as the Von Karman Institute.			
(U) In FY 2004: Continue on-site coordination with international research organizations and support international visits of high-level DoD delegations. Sustain and fund Air Force commitment to NATO-affiliated research institutes, such			

Exhibit R-2a, RDT&E Project Justification		DATE February 2004	
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	as the Von Karman Institute.			
(U)	In FY 2005: Not Applicable. Note: In FY 2005, these activities will be moved to the "international science and technology" efforts later in this Project.			
(U)				
(U)	MAJOR THRUST: Foster international science and technology cooperation by supporting the Air Force's international strategy mission. Identify and obtain unique foreign research capabilities through the international technology liaison missions of the European Office of Aerospace Research and Development and the Asian Office of Aerospace Research and Development. Note: Prior to FY 2005, these activities were part of other efforts earlier in this Project.	0.000	0.000	6.061
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Not Applicable.			
(U)	In FY 2005: Provide centralized cooperation expertise, support international technology liaison missions, and identify unique research capabilities of high interest to the US Air Force. Support international visits of high-level DoD delegations and provide primary interface to coordinate international participation among DoD organizations. Aid in Air Force fiscal commitments to foreign NATO-affiliated research institutes.			
(U)				
(U)	MAJOR THRUST: Support scientist and engineer development assuring the Air Force of continuing availability of superior technical talent and forging Air Force Research Laboratory relationships with premiere scientists.	1.927	2.085	3.577
(U)	In FY 2003: Supported scientist and engineer research program at U.S. colleges and universities, including historically black colleges and universities, Hispanic serving institutions, and other minority institutions. Improved awareness of Air Force research needs throughout the civilian scientific community, while simultaneously identifying and recruiting the best scientific talent to participate in critical Air Force research.			
(U)	In FY 2004: Support scientist and engineering research programs at U.S. colleges and universities, including historically black colleges and universities, Hispanic serving institutions, and other minority institutions. Improve awareness of Air Force research needs throughout the civilian scientific community, while simultaneously identifying and recruiting the best scientific talent to participate in critical Air Force research.			
(U)	In FY 2005: Continue to support scientist and engineering research programs at U.S. colleges and universities, including historically black colleges and universities, Hispanic serving institutions, and other minority institutions. Enhance awareness of Air Force research needs throughout civilian scientific community, while simultaneously identifying/ recruiting the best scientific talent to participate in critical Air Force research.			
(U)	Total Cost	6.962	7.346	9.638

Exhibit R-2a, RDT&E Project Justification		DATE February 2004
BUDGET ACTIVITY **01 Basic Research**	PE NUMBER AND TITLE **0601102F Defense Research Sciences**	PROJECT NUMBER AND TITLE **4113 External Research Programs Interface**

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

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	Cost to Complete	Total Cost
(U) Related Activities:									
(U) PE 0601103D, University Research Initiative.									
(U) PE 0602102F, Materials.									
(U) PE 0602201F, Aerospace Flight Dynamics.									
(U) PE 0602202F, Human Effectiveness Applied Research.									
(U) PE 0602203F, Aerospace Propulsion.									
(U) PE 0602204F, Aerospace Avionics.									
(U) PE 0602269F, Hypersonic Technology Program.									
(U) PE 0602500F, Multi-Disciplinary Space Technology.									
(U) PE 0602601F, Space Technology.									
(U) PE 0602602F, Conventional Munitions.									
(U) PE 0602702F, Command, Control and Communication.									

(U) D. Acquisition Strategy

Not Applicable.