PE NUMBER: 0602601F
PE TITLE: Space Technology 1

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BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology 1

	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	74.889	101.539	88.909	89.644	97.609	118.971	126.742	0.000	0.000
1010	Space Survivability & Surveillance	30.276	43.080	40.002	39.466	42.160	40.843	41.510	0.000	0.000
4846	Spacecraft Payload Technologies	12.431	16.937	19.553	20.608	20.735	35.740	39.529	0.000	0.000
5018	Spacecraft Protection Technology	4.355	4.011	2.630	2.442	2.303	2.434	2.516	0.000	0.000
8809	Spacecraft Vehicle Technologies	27.827	37.511	26.724	27.128	32.411	39.954	43.187	0.000	0.000

Note: In FY 2003, Project 1010 was split, with efforts focused on protecting spacecraft from manmade threats being transferred into Project 5018.

(U) A. Mission Description and Budget Item Justification

This PE focuses on four major areas. First, space environmental protection develops technologies to understand, mitigate, and exploit effects of weather and geophysics environments on the design and operation of Air Force systems. Second, spacecraft payload technologies improve satellite payload operations by investigating advanced component and subsystem capabilities. Third, spacecraft protection develops technologies for protecting U.S. space assets in potential hostile settings. The last major area, spacecraft vehicles focuses on spacecraft platform, payload, and control technologies, and their interactions. Note: In FY 2004, Congress added $5.0 million for High-frequency Active Auroral Research Program (HAARP) Space Technology, $2.1 million for Electromagnetic Gradiometer Research, $1.8 million for Mixed Signal Very Large Scale Integrated (Circuits) for Space Vehicle Communications Subsystems, $3.0 million for Technology Satellite of the 21st Century, $1.2 million for Substrates for Solar Cells, $1.0 million for Integrated Control for Autonomous Space Systems, $1.5 million for Elastic Memory Composites, $1.8 million for Elastic Memory Composite Materials, $1.5 million for Converted Silicon Carbide for High Performance Optic Structures, and $2.3 million for Affordable Multi-Junction Solar Cells.

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

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

		FY 2003	FY 2004	FY 2005
(U)	Previous President's Budget	76.239	83.240	90.810
(U)	Current PBR/President's Budget	74.889	101.539	88.909
(U)	Total Adjustments	-1.350	18.299	
(U)	Congressional Program Reductions	0.000	-2.032	
	Congressional Rescissions		-0.869	
	Congressional Increases	0.000	21.200	
	Reprogrammings	-0.006		
	SBIR/STTR Transfer	-1.344		
(U)	Significant Program Changes:			

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Changes to this PE since the previous President's Budget are due to higher Air Force priorities.

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BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602601F Space Technology 1

PROJECT NUMBER AND TITLE: 1010 Space Survivability & Surveillance

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
1010 Space Survivability & Surveillance	30.276	43.080	40.002	39.466	42.160	40.843	41.510	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

Note: In FY 2003, Project 1010 was split, with efforts focused on protecting spacecraft from manmade threats being transferred into Project 5018.

(U) A. Mission Description and Budget Item Justification

This project develops the technologies to exploit the space environment for the warfighter's benefit. The project focuses on characterizing and forecasting the battlespace environment for realistic space system design, modeling, and simulation, as well as the battlespace environment's effect on space systems' performance. It includes technologies to specify and forecast the environment from "mud to sun" for planning operations and ensuring uninterrupted system performance, optimize space-based surveillance operations, and allow the opportunity to mitigate or exploit the space environment for both offensive and defensive operations. Finally, this project includes the seismic research program that supports national requirements for monitoring nuclear explosions.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Develop technologies for specifying, monitoring, predicting, and controlling space environmental conditions hazardous to Department of Defense (DoD) operational space systems in order to improve performance, reduce cost, and increase operational lifetimes.	3.155	3.199	4.207

(U) In FY 2003: Validated algorithms for tracking solar plasma clouds to Earth and predicting onsets of adverse effects on DoD systems. Developed models and algorithms for propagation of solar/geomagnetic activity for spacecraft susceptibility to single event upsets. Completed initial dynamic radiation belt model with real-time data assimilation for spacecraft hazard forecasting.

(U) In FY 2004: Develop advanced space weather forecasting models combining remote sensing of interplanetary clouds with in situ plasma and fields data. Validate dynamic radiation belt model for satellite hazard forecasts with newly acquired data sets from operational DoD satellites. Develop advanced technology solar telescope for detecting and forecasting explosive solar events that generate spacecraft-damaging energetic particle events and initiate plasma clouds responsible for adverse communication and navigation effects. Develop capability to test sub-micron and nano-scale technology concepts for extremely small space hazard detectors.

(U) In FY 2005: Upgrade initial version of dynamic radiation belt specification and forecast model to include extreme solar shock events responsible for the worst radiation conditions. Complete conceptual design of advanced, high-resolution solar telescope and begin fabrication of next-generation solar hazard forecasting tool. Test novel concepts to detect high-energy space particles using micro- and nano-technology based sensors suitable for inclusion in microsatellite constellations to specify space weather. Build empirical solar flare forecast algorithms and initiate physics based model development to improve accuracy and lead-times for prediction of debilitating explosive events.

(U)

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(U)	MAJOR THRUST: Develop real-time infrared backgrounds clutter code, spectral signature libraries, target detection techniques, and decision aids for application to space-based surveillance, laser weapons, and countermeasure systems, including detection of low-observable targets.	7.650	9.880	13.008
(U)	In FY 2003: Validated background models with new experimental data and applied to surveillance system design trades and performance analyses. From field measurements, determined trade space for space system for earliest detection of theater ballistic missiles in boost phase. Upgraded models of atmospheric turbulence sources and improved laser weapon performance prediction model of airborne and space-based systems. Developed advanced techniques to exploit hyperspectral data and validate hyperspectral performance modeling and simulation codes. Developed design requirements for space-based sensor to obtain sub-pixel, high spectral resolution measurements of optical/infrared backgrounds for next-generation operational surveillance, target identification, and damage assessment systems.			
(U)	In FY 2004: Develop all-altitude, sub-pixel infrared background radiance model for atmospheric transmission of extended radiance sources such as missile hard bodies and plumes. Test and validate decision aids and turbulence performance prediction tools, including theater ballistic missile boost phase negation, on airborne laser platform. Expand models for other high-energy laser systems and explore a forecasting capability for high altitude turbulence effects on aircraft platforms. Develop sensors, algorithms, and clutter removal techniques for space-based hypertemporal imaging sensor. Incorporate spectral signature variability into simulation codes to improve performance predictions. Collect high quality spectral data from existing systems and evaluate system requirements for theater surveillance and area search missions.			
(U)	In FY 2005: Validate and deliver all-altitude, sub-pixel infrared background radiance model for extended radiance sources. Upgrade and improve atmospheric turbulence models for use in decision aids for tactical high-energy laser systems. Improve turbulence forecast technology for a turbulence decision aid for high altitude air vehicles. Develop advanced on-chip digital signal processing technologies for real-time hypertemporal detection. Validate day/night spectral exploitation algorithms and related signature databases for specific environments such as littoral, agricultural, desert, and woodlands. Use validated simulations to evaluate candidate technologies for spectral theater surveillance and area search missions.			
(U)				
(U)	MAJOR THRUST: Develop artificial intelligence techniques, forecasting tools, and sensors for improved ionospheric specification and forecasting, including communications/navigation outage forecasting, space-based geolocation demonstrations, and determination and prediction of radar degradation.	7.114	6.708	5.966
(U)	In FY 2003: Developed data processing software and hardware architecture for collecting and analyzing ground and space data to provide near-real-time nowcasts and forecasts of ionospheric hazards. Validated nowcast and forecast predictions using ground and space-based experimental databases and incorporated results into forecast tool risk reduction. Improved techniques to track the motion of the highly structured plasma in the polar region, to enhance the			

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reliability of ionospheric specification in high latitude theaters. Developed multi-scale algorithms to increase reliability of global ionospheric forecasts.

(U) In FY 2004: Develop nowcasting and forecasting validation algorithms applicable to concepts such as the Communication/Navigation Outage Forecasting System (C/NOFS) Advanced Concept Technology Demonstration. Integrate validation algorithms into ionospheric specification and forecast modeling architecture. Validate communication and navigation outage forecasts with C/NOFS satellite and ground-based data to demonstrate utility of outage warning due to scintillation. Integrate polar region plasma tracking models into global models of scintillation to provide seamless equator-to-pole outage specification. Validate multi-scale algorithms and data assimilation techniques to increase reliability of global ionospheric electron profile specifications and forecasts to improve radar and geolocation performance. Explore concept development of scintillation mitigation techniques to overcome satellite-to-ground link degradation in real-time.

(U) In FY 2005: Generate communication/navigation outage nowcasts and forecasts due to ionospheric scintillation to give the warfighter improved battlefield situational awareness and operational flexibility. Develop validated ionospheric specification and forecast models and products using results from military evaluation of C/NOFS Advanced Concept Technology Demonstration. Investigate ionospheric scintillation technologies to develop techniques for longer-term outage forecasting. Complete pole-to-equator scintillation specification model giving global real-time hazard alerts. Couple magnetospheric data assimilation and forecast models to validated ionospheric electron profile models to improve geolocation accuracy and increase forecast lead times for radar operations. Develop combined laboratory/field tests to demonstrate feasibility of receiver and transmitter technologies to mitigate hazardous scintillation conditions.

(U)

(U) MAJOR THRUST: Develop High-frequency Active Auroral Research Program site transmitting and diagnostic instrument infrastructure.	0.000	9.684	10.000

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Continue populating the high frequency transmitter array to its full capacity of 180 array elements and 3.6 megawatt radiated output power.

(U) In FY 2005: Continue populating the high frequency transmitter array to its full capacity of 180 array elements and 3.6 megawatt radiated output power.

(U)

(U) MAJOR THRUST: Develop basic seismic technologies to support national requirements for monitoring nuclear explosions with special focus on monitoring regional events located at distances less than 2,000 km from the sensors.	0.000	6.569	6.821

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Conduct seismic research such as seismic energy partitions for local and regional events, magnitudes and source physics; seismic calibration and ground truth collection; and seismic detection, location, and

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	discrimination technologies. Perform observational studies of seismic wave propagation and collect seismic propagation characteristics of the Eurasian landmass.			
(U)	In FY 2005: Provide updated seismic codes for operational use. Continue efforts on seismic energy partition, magnitudes, and source physics; seismic calibration; seismic detection, location and discrimination; and observational studies of seismic wave propagation, including propagation in Eurasia. Assess future direction of seismic research based on results obtained so far, and continue to conduct seismic research on these and other topics of interest to the Air Force.			
(U)				
(U)	CONGRESSIONAL ADD: Seismic Monitoring Research.	2.920	0.000	0.000
(U)	In FY 2003: Developed basic seismic technologies to support national requirements for monitoring nuclear explosions. Enhanced United States capabilities in seismic monitoring of nuclear explosions, with special focus on monitoring regional events located at distances less than 2,000 km from the sensors. Performed theoretical and experimental seismology studies to detect, locate, and characterize nuclear explosions.			
(U)	In FY 2004: Not Applicable.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	CONGRESSIONAL ADD: High-frequency Active Auroral Research Program (HAARP) Incoherent Scatter Radar (ISR).	2.529	0.000	0.000
(U)	In FY 2003: Developed a modular approach for installation of an ISR diagnostic at the HAARP facility. Completed site infrastructure for the ISR and preliminary support structure. Acquired and installed a modular, eight-panel, ISR transmit/receive sub-array. Conducted a research program to characterize radio-wave interactions and processes in the ionosphere using the sub-array as a powerful radar diagnostic instrument in conjunction with the HAARP high power high frequency transmitting array.			
(U)	In FY 2004: Not Applicable.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	CONGRESSIONAL ADD: High-frequency Active Auroral Research Program (HAARP) Experimentation.	4.963	4.958	0.000
(U)	In FY 2003: Develop the HAARP site transmitting and diagnostic instrument infrastructure. Provided facility management and environmental oversight. Performed research programs to assess the viability of exploiting Extremely Low Frequency/Very Low Frequency waves generated in the ionosphere for military applications. Conducted research programs to characterize high power radio wave interactions in the ionosphere and space, including the generation of irregularities and optical emissions and to exploit the HAARP diagnostic instruments for space weather specification. Developed real-time diagnostic and data analysis software and web displays.			
(U)	In FY 2004: Develop planned diagnostic infrastructure at the HAARP site. Provide facility management and			

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environmental oversight functions. Conduct research programs concentrating on the generation of Extremely Low Frequency/Very Low Frequency waves in the ionosphere and their applications to subsurface communications, the detection of underground structures, and the reduction of charged particle populations in the earth's radiation belts.

(U) In FY 2005: Not Applicable.

(U)

(U)	CONGRESSIONAL ADD: Electromagnetic Gradiometer Research.	1.945	2.082	0.000

(U) In FY 2003: Investigated, enhanced, and tested electromagnetic radiometry technologies for the detection of underground structures. Conducted field demonstrations of a miniature and rugged man-portable hardware system using Very Low Frequency waves to detect underground structures. Designed a system with improved detection algorithms, frequency agility, and remote data access for unmanned aero vehicle/airborne applications. Developed techniques to enhance the operational viability of both the man-portable and airborne systems.

(U) In FY 2004: Miniaturize a recently completed, rugged, man-portable hardware system. Assess the viability of an unmanned ground-based, randomly distributed-array detection concept. Develop an airborne application.

(U) In FY 2005: Not Applicable.

(U)	Total Cost	30.276	43.080	40.002

(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 0305160F, Defense Meteorological Satellite Program.
(U) PE 0601102F, Defense Research Sciences.
(U) PE 0602204F, Aerospace Sensors.
(U) PE 0305111F, Weather Systems.
(U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.

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(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 02 Applied Research	PE NUMBER AND TITLE: 0602601F Space Technology 1	PROJECT NUMBER AND TITLE: 4846 Spacecraft Payload Technologies	

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
4846	Spacecraft Payload Technologies	12.431	16.937	19.553	20.608	20.735	35.740	39.529	0.000	0.000
	Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

This project develops advanced technologies that enhance spacecraft payload operations by improving component and subsystem capabilities. The project focuses on four primary areas: (1) development of advanced, space-qualified, survivable electronics, and electronics packaging technologies; (2) development of advanced space data generation and exploitation technologies, including infrared, Fourier Transform hyperspectral imaging, polarimetric sensing, and satellite antenna subsystem technologies; (3) development of high-fidelity space simulation models that support space-based surveillance and space asset protection research and development for the warfighter; and (4) development of advanced networking, radio frequency, and laser communications technologies to support next generation satellite communication systems.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Develop advanced infrared device technologies for space applications that support hardened focal plane detector arrays to enable acquisition, tracking, and discrimination of bodies such as decoys, satellites, and warheads throughout their trajectory.	3.518	2.841	4.083

(U) In FY 2003: Evaluated two- and three-color detector and continued development of multi-color detectors and tunable and broadband gratings. Designed and fabricated selected concepts for future longer wavelength infrared detectors and infrared detectors with optimal background-limited performance for stressing, low photon noise, and space backgrounds. Completed design study of next generation long and very long wavelength infrared detector concepts, including quantum wells and strained layer superlattices, as lower cost, higher performance alternatives to mercury cadmium telluride. Evaluated delivered radiation-hardened cryogenic multiplexers for lower background, space infrared detector arrays.

(U) In FY 2004: Fabricate and characterize strained-layer superlattice detectors and use results to modify designs to improve absorption efficiency and eliminate manufacturing or operationally induced defects. Complete the two-dimensional focal plane array development effort by identifying, designing, and fabricating the appropriate cryogenic detector multiplexers required for transitioning the technology. Begin development of infrared detector and detector read-out circuit technologies for next generation surveillance systems with projected requirements for adaptive, re-configurable, and polarimetric capabilities.

(U) In FY 2005: Incorporate design changes into the fabrication process and continue wafer growth of strained-layer superlattice detector structures and other promising technologies. These alternatives to mercury cadmium telluride offer both improved performance at a given operating temperature and comparable performance at higher operating temperatures. Evaluate promising "on-focal plane array polarimetric" concepts developed to meet projected capability requirements of the next generation surveillance systems.

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BUDGET ACTIVITY **02 Applied Research**	PE NUMBER AND TITLE **0602601F Space Technology 1**	PROJECT NUMBER AND TITLE **4846 Spacecraft Payload Technologies**		

(U)				
(U)	MAJOR THRUST: Develop spectral sensing and data exploitation methodologies for military imaging and remote sensing applications.	0.832	0.752	1.004
(U)	In FY 2003: Assessed technology and modeling for understanding the electro-optical/infrared polarimetric phenomenology. Evaluated initial polarimetric signature model capability and validated with measured data. Developed capability to integrate polarimetric models into modeling, simulation, and analysis for space-based surveillance applications.			
(U)	In FY 2004: Complete initial assessment of technology and modeling for understanding the electro-optical/infrared spectral polarimetric phenomenology. Demonstrate partially validated polarimetric signature model capability and continue validation with measured data from ongoing field collects. Integrate initial polarimetric models into modeling, simulation, and analysis architecture for space-based surveillance applications.			
(U)	In FY 2005: Complete assessment and documentation of electro-optical/infrared spectral polarimetric phenomenology understanding. Demonstrate validated polarimetric signature model capability and develop new code upgrades and validation with measured data from on-going field collections. Demonstrate integration of spectral polarimetric models into scene simulation architecture for space-based surveillance applications.			
(U)				
(U)	MAJOR THRUST: Develop technologies for space-based payload components such as low power, high performance, radiation-hardened electronic devices, micro-electro-mechanical system (MEMS) devices, and advanced electronics packaging for next generation high performance space electronics.	3.448	3.731	3.490
(U)	In FY 2003: Enhanced the switching speed and durability of the chalcogenide material by ten times for improved devices through additional silicon-on-insulator radiation research. Extended the design of the monolithically integrated low power, silicon-based quantum-sized devices to include non-traditional electronic materials. Improved the speed of the radiation-hardened nonvolatile digital memories. Characterized the analog memories and enhanced resolution to an eight-bit equivalent. Built space-qualified MEMS reliability test devices and chip-scale packages for ground and flight insertion. Built reconfigurable analog array packaging structures.			
(U)	In FY 2004: Research radiation effects in electronics components based on emerging silicon-on-insulator, sapphire, or other radio frequency and analog technology compatible substrates. Evaluate monolithically integrated low power, silicon-based quantum-sized devices for system-on-a-chip applications. Develop radiation hardening design techniques to enable fabrication of electronics on commercial lines. Evaluate architecture and components supporting analog memory. Build micro-electro-mechanical system based switches supporting complex switching harnesses in support of self-adaptable spacecraft hardware. Develop architectures and packaging approaches in support of reconfigurable space systems.			
(U)	In FY 2005: Research radiation effects in electronics built with hardness by design methods at state-of-the-art manufacturing plants. Evaluate chalcogenide-based reconfigurable electronics providing ten fold performance			

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	improvement and self-repair capabilities. Build monolithically integrated low-power, silicon-based quantum-sized devices for system-on-a-chip applications. Establish tools for hardness-by-design part manufacture and demonstrate ten-fold decrease in manufacturing cost. Design switches on chip, board, and intra-board level supporting self-adaptable, self-healing spacecraft hardware. Develop and evaluate architectures and packaging approaches in support of reconfigurable space systems.			
(U)				
(U)	MAJOR THRUST: Develop modeling, simulation, and analysis tools for space-based surveillance systems, rendezvous and proximity operations, optical/infrared imaging space systems, and distributed satellite architecture payloads.	2.347	1.255	2.874
(U)	In FY 2003: Extended simulation architecture to support flight experiment ground-to-space segment simulation including spacecraft bus and payload modeling development. The simulation architecture can be used for objective system-of-systems assessment.			
(U)	In FY 2004: Further extend simulation architecture to support flight experiment ground-to-space segment simulation. Extend the architecture for use in objective system-of-systems, military utility assessment. Develop extensions to the simulation architecture to address missions associated with responsive space, space capability protection, and counterspace. Develop enhancements to optical/infrared imaging system simulation to include polarimetric effects.			
(U)	In FY 2005: Ready the simulation architecture to support flight experiment simulation and data validation for experiments on deployable antenna technology, adaptive avionics, autonomous command/control software, and responsive space technologies. Continue to develop extensions to the simulation architecture to address missions associated with responsive space, space capability protection, and counterspace. Develop further enhancements to optical/infrared imaging system simulation to include polarimetric effects.			
(U)				
(U)	MAJOR THRUST: Develop advanced architectures and performance characterization tools for future large, lightweight, modular space antennas.	0.924	0.957	0.870
(U)	In FY 2003: Extended antenna architecture and algorithms developed for performance characterization of modular phased array antenna tiles to multi-beam, wider-bandwidth, multi-mode operation. Supported development of advanced low-power, low-noise amplifiers, integrated wide-bandwidth radiators, and active radio frequency manifold control technologies. Built a testbed to simulate performance of multi-beam, wide-bandwidth phased array antenna tiles and integrated antenna models.			
(U)	In FY 2004: Refine transmit/receive testbed, enhancing the performance of the phased-array antenna subsystems and integrated antenna modules using miniaturized active radio frequency components and planar wide-bandwidth radiators. Characterize performance of new wide-bandwidth antenna subsystems and correlate results to model predictions; update models based on actual performance. Develop algorithms for performance characterization of sparse cooperating apertures and for advanced antenna array calibration.			

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(U) In FY 2005: Investigate subsystems architectures for sparse membrane arrays for next generation agile beam control and a smart antenna that extends transmit/receive antenna technology to autonomous beam control. Design, fabricate, and characterize performance of autonomous beam control subsystem. Correlate results to model predictions and update models based on actual performance.			
(U)			
(U) MAJOR THRUST: Develop bandwidth efficient modulation and high bandwidth communications technologies to support next generation satellite communication systems.	0.000	1.872	1.790
(U) In FY 2003: Not Applicable.			
(U) In FY 2004: Explore architecture studies and guide technology investment in support of satellite communications roadmap. Develop technology standards and system designs for integrating multiple airborne intelligence, surveillance, and reconnaissance assets into single space platforms.			
(U) In FY 2005: Further explore architecture studies and guide technology investment in support of satellite communications roadmap. Expand development of technology standards and system designs for integrating multiple airborne intelligence, surveillance, and reconnaissance assets into single space platforms.			
(U)			
(U) MAJOR THRUST: Develop technologies for multi-access laser communications terminals. Assess the maturity of single access terminal components and their applicability to a multi-access terminal design.	0.000	3.744	5.442
(U) In FY 2003: Not Applicable.			
(U) In FY 2004: Develop standards for combining multiple airborne intelligence, surveillance, and reconnaissance and space asset feeds into a single optical data path. Design a laboratory multi-access terminal testbed.			
(U) In FY 2005: Further develop standards for combining multiple airborne intelligence, surveillance, and reconnaissance and space asset feeds into a single optical data path. Continue design of a laboratory multi-access terminal testbed.			
(U)			
(U) CONGRESSIONAL ADD: Mixed Signal Very Large Scale Integrated (VLSI) [Circuits] for Space Vehicle Communication Subsystems.	1.362	1.785	0.000
(U) In FY 2003: Developed radiation-hard analog circuit elements for mixed signal VLSI circuits for secure high-bandwidth intra-satellite and satellite-ground station communications. Radiation tested and characterized commercial state-of-the-art mixed signal components to determine the feasibility of employing commercial foundry technologies for space applications. Designed and fabricated innovative circuit configurations and test devices using new radiation-hard analog elements and circuit architectures.			
(U) In FY 2004: Develop improved, radiation-hard, analog circuit elements for mixed-signal VLSI circuits. Refine and employ results from radiation testing and characterization of commercial state-of-the-art mixed-signal components to improve designs using commercial foundry technologies for space applications. Design and fabricate innovative			

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circuit configurations and test devices using new radiation-hard analog elements and circuit architectures.

(U) In FY 2005: Not Applicable.

(U) Total Cost	12.431	16.937	19.553

(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 0603401F, Advanced Spacecraft Technology. This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication.									

(U) D. Acquisition Strategy

Not Applicable.

Exhibit R-2a, RDT&E Project Justification			DATE: February 2004
BUDGET ACTIVITY: 02 Applied Research	PE NUMBER AND TITLE: 0602601F Space Technology 1	PROJECT NUMBER AND TITLE: 5018 Spacecraft Protection Technology	

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
5018 Spacecraft Protection Technology	4.355	4.011	2.630	2.442	2.303	2.434	2.516	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

Note: In FY 2003, Project 1010 was split with efforts focused on protecting spacecraft from manmade threats being transferred into Project 5018.

(U) A. Mission Description and Budget Item Justification

This project develops the technologies for protecting U.S. space assets in potential hostile environments to assure continued space system operation without performance loss in support of warfighter requirements. The project focuses on identifying and assessing spacecraft system vulnerabilities, developing threat warning technologies, and developing technologies to mitigate the effects of both intentional and unintentional threats.

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Develop key satellite threat warning technologies and tools for high value satellite asset defense.	0.943	1.285	0.911
(U) In FY 2003: Developed initial components of a high performance multiple threat sensors satellite protection system, improving technical performance of the sensor suite while still minimizing cost, power, and weight. Investigated integration of the miniature radio frequency receiver, laser detector, and ionospheric specification system with advanced reconfigurable processor electronics for the first generation system. Assessed feasibility of using a single antenna for performing radio frequency (RF) geolocation from a low-earth-orbit satellite. Investigated laser and RF false alarm rejection/mitigation and anomaly resolution and management techniques.			
(U) In FY 2004: Develop and bench-test high performance multi-threat warning on-board sensors. Explore reconfigurable processor electronics capability and build testbed in support of multi-threat warning sensors. Analyze light, adaptable single antenna performance for threat detection and geolocation applications. Complete false alarm research for relevant threats. Select antenna technology for wide-band and narrow-band threat detectors for multi-threat capability space experiment.			
(U) In FY 2005: Update microsatellite threat characteristics. Select most promising proximity sensor technology and begin development of a experimental proximity sensor. Design and report ground and space demonstration plan for the purpose of confirming proximity sensor performance.			
(U)			
(U) MAJOR THRUST: Develop high value space asset defensive capabilities.	1.314	0.847	0.601
(U) In FY 2003: Conducted threat reporting risk reduction Space Shuttle experiment and performed post-experiment data and system performance analysis.			
(U) In FY 2004: Design and fabricate miniaturized narrowband RF attack reporting receiver with of goal of five times reduction in power and size.			
(U) In FY 2005: Select most promising defensive weapon technology and begin development of experimental defensive			

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	capabilities. Design and report ground and space demonstration plan for the purpose of confirming defensive capability performance.			
(U)				
(U)	MAJOR THRUST: Develop techniques to exploit existing on-board inherent satellite resources, satellite-as-a-sensor, and self aware satellite technologies as a first-line threat detection system.	0.347	0.831	0.590
(U)	In FY 2003: Investigated use of systems on currently fielded or launch ready satellites for preliminary determination of radio frequency/laser illumination or kinetic impact. Assessed the use of telemetry, state-of-health data, and other appropriate data for event determination.			
(U)	In FY 2004: Develop technology for currently fielded or launch-ready satellites to detect anomalies that result from radio frequency/laser illumination or kinetic impact. Explore use of on board resources such as telemetry or state-of-health data for anomaly determination as a zero added power/weight solution and assess the limits of this technique. Conduct laboratory proof of concept for selected subsystems.			
(U)	In FY 2005: Conduct ground simulation demonstration of a combined satellite-as-a-sensor system. The simulation includes data fusion, unique radio frequency location tool, simulated laser sensor, simulated proximity sensor, and satellite as a sensor test bed.			
(U)				
(U)	MAJOR THRUST: Develop techniques for monitoring and assessing electromagnetic interference and compatibility between ultra-sensitive payload sensors for space systems that support space weather forecasting.	1.751	1.048	0.528
(U)	In FY 2003: Integrated payload for the Communications/Navigation Outage Forecast System (C/NOFS) Advanced Concept Technology Demonstration. Designed, developed, and tested serial communications hardware and software for command and data handling spacecraft sub-system risk reduction for real-time space weather forecasting. Validated data compression techniques with payload sensor data and apply to space flight software for demonstrating space weather forecasting.			
(U)	In FY 2004: Continued to prepare for the space experiment demonstration of C/NOFS.			
(U)	In FY 2005: Conduct space experiment demonstration of C/NOFS. Perform measurements of key ionospheric and scintillation parameters needed for input to ionospheric specification and forecast models. Assess data for electromagnetic interference effects on ultra-sensitive payload sensors. Assess payload performance in measuring ionospheric and scintillation parameters needed for space weather support in theater and for mission planners and other users.			
(U)	Total Cost	4.355	4.011	2.630

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

(U) D. Acquisition Strategy

Not Applicable.

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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
8809 Spacecraft Vehicle Technologies	27.827	37.511	26.724	27.128	32.411	39.954	43.187	0.000	0.000
Quantity of RDT&E Articles	0	0	0	0	0	0	0		

(U) A. Mission Description and Budget Item Justification

This project focuses on seven major space technology areas: spacecraft platforms (e.g., structures, controls, power, and thermal management); space-based payloads (e.g., survivable electronics); satellite control (e.g., software for autonomous distributed satellite formation flying, signal processing, and control); modeling and simulation of space-based systems; satellite protection technologies (e.g., space environment effects, debris prediction, and threat warning/attack reporting); microsatellite technologies; and integrated experiments of advanced technologies for transition to planned systems (e.g., payload/platform/launch vehicle merging).

(U) B. Accomplishments/Planned Program ($ in Millions)	FY 2003	FY 2004	FY 2005
(U) MAJOR THRUST: Develop technologies for advanced space platform subsystems such as cryocoolers, compact, high efficiency solar power cells and arrays, and innovative power generation concepts.	3.240	3.871	4.188
(U) In FY 2003: Improved accuracy of cryocooler modeling tools and the identification of mechanisms that limit operational life and degrade cryocooler subsystem performance. Fabricated and tested a 32% efficient solar cell. Proved production capacity for a 10% efficient thin-film solar cell.			
(U) In FY 2004: Complete identification of mechanical and long-term failure mechanisms for assessing cryocooler performance and reliability. Build first generation analytical performance prediction models, empirical measurements, and thermophysical fluid flow and heat transfer models for low-temperature cryocooler regenerator performance. Investigate technology development to improve cryocooler capability and performance for regenerative and recuperative cycle cryocoolers. Fabricate multijunction solar cells using lattice-mismatch technology on lower-cost silicon wafers with efficiencies that break even with the efficiency of current production multijunction 28% Germanium solar cells. Demonstrate 10% efficient thin-film solar cells on polymer substrates.			
(U) In FY 2005: Build second-generation empirically verified thermophysical performance models for cryocooler regenerators. Further investigate technology development to improve cryocooler capability and performance for regenerative and recuperative cycle cryocoolers. Build modeling and simulation capability for complex thermodynamic cycle coolers. Develop a 30% efficient crystalline multijunction solar cell based on lattice-mismatch technology. Fabricate 10% efficient thin-film, monolithically integrated solar cell.			
(U)			
(U) MAJOR THRUST: Develop technologies for advanced space platform structures such as structural controls for vibration suppression, multifunctional structures, deployable large aperture optical arrays, and lightweight composite satellite and launch vehicle structures.	7.576	9.500	7.274
(U) In FY 2003: Flight tested full-spacecraft vibration suppression to better isolate and protect spacecraft from the harsh			

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launch vehicle environment. Potential to decrease vibration and acoustic stresses on spacecraft, thereby reducing overall cost of spacecraft design. Characterized performance of multifunctional bus structure for small spacecraft.

(U) In FY 2004: Complete characterization of multifunctional small spacecraft bus. Initiate development of tunable nanotechnology-enhanced lightweight space structures. Develop lightweight structures and precision structural controls for large-aperture space optics. Develop low-shock and precision deployment mechanisms.

(U) In FY 2005: Perform material characterization of tunable nanotechnology-enhanced lightweight space structures. Fabricate and test engineering concepts for lightweight structures and precision structural controls for large-aperture space optics. Fabricate and test low-shock and precision deployment mechanisms for satellite separation and subsystem deployment.

(U)

(U) MAJOR THRUST: Develop microsatellite (10-100kg) technologies and integrated microsatellite technology concepts. The innovative microsatellite architectures and advanced satellite bus technologies could enable applications such as space protection, counterspace capabilities, sparse aperture sensing, on-orbit formation flying, inter-satellite communications, distributed processing, and responsive payloads.	9.944	4.641	2.106

(U) In FY 2003: Completed fabrication and qualification testing of subsystem hardware, including avionics, Hall-effect thrusters, and high-density memory. Completed fabrication and environmental testing of bus structure. Conducted detailed studies for potential new mission payloads.

(U) In FY 2004: Note: The planned microsatellite technology program was re-oriented to apply modeling and simulation techniques to evaluate the technical feasibility, military utility, and cost effectiveness of a multi-aperture system to meet future space-based radio frequency intelligence, surveillance, and reconnaissance needs.

(U) In FY 2005: Plan to complete evaluation of the technical feasibility, military utility, and cost effectiveness of a multi-aperture system to meet future space-based radio frequency intelligence, surveillance and reconnaissance needs.

(U)

(U) MAJOR THRUST: Develop flight experiments to address key scientific and technological problems in order to improve the capabilities of existing operational space systems and to enable new transformational space capabilities.	0.000	7.303	13.156

(U) In FY 2003: Not Applicable.

(U) In FY 2004: Evaluate structures, controls, and isolation technologies for maturity for space flight experiments. Design and develop a deployable structures space flight experiment for potential space-based radar applications. Develop initial efficient, large, deployable antennas for space-borne sensors for radiation belt remediation. Start initial designs for deployable thin film photovoltaic arrays suitable for middle-earth-orbit flight experiment.

(U) In FY 2005: Complete design of a deployable structures space flight experiment for potential space-based radar applications. Integrate lightweight deployable structures with efficient, large, deployable antennas for space-borne sensors and deployable thin film photovoltaic arrays for midele-earth orbit flight experiment of these technologies.

(U)

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(U) CONGRESSIONAL ADD: Lightweight and Novel Structures for Space.	0.975	0.000	0.000
(U) In FY 2003: Developed technologies for advanced mirror systems and space structures, including improved advanced mirror fabrication techniques and methods for enhancing performance of the associated structural systems required to support sensors in space. Current fabrication methods are labor and time intensive, and the product is heavy, expensive, and falls short of achieving technical requirements. Investigated non-traditional and innovative composite fabrication techniques, focusing on accelerated fabrication techniques and dimensionally stable materials.			
(U) In FY 2004: Not Applicable.			
(U) In FY 2005: Not Applicable.			
(U)			
(U) CONGRESSIONAL ADD: Carbon Foam for Aircraft and Spacecraft.	0.448	0.000	0.000
(U) In FY 2003: Developed carbon foam-based structures for aircraft and spacecraft. Investigated the performance requirements of structures for currently planned airborne and space-based systems and assessed carbon foam blends and types for use in optical backing structures and the optical mounts for those systems. Downselected to the optimal carbon foam formulation and completed preliminary designs of an optical backing structure and optical mount.			
(U) In FY 2004: Not Applicable.			
(U) In FY 2005: Not Applicable.			
(U)			
(U) CONGRESSIONAL ADD: Technology Satellite of the 21st Century (TechSat-21).	2.920	2.975	0.000
(U) In FY 2003: Completed integration and test of microsatellite system flight software. Evaluated performance of flight navigation system with live Global Positioning Signals to support potential mission applications ranging from distributed aperture formations to space surveillance, threat warning, and protection.			
(U) In FY 2004: Develop and ground test advanced subsystem flight units that could demonstrate responsive microsatellite bus technologies. Key advances in microsatellite bus technologies include high power density lithium polymer batteries, lightweight thin-film solar arrays with micro-gimbals, and a modular 160-640 Gbyte non-volatile mass memory subsystem. This microsatellite bus technology development program could support mission applications ranging from distributed aperture formations to space surveillance, threat warning, and protection.			
(U) In FY 2005: Not Applicable.			
(U)			
(U) CONGRESSIONAL ADD: Substrates for Solar Cells.	1.362	1.190	0.000
(U) In FY 2003: Developed high temperature polymer substrates for thin film solar cells for next generation flexible, thin film solar arrays. These thin film arrays will be three to five times lighter, cost five times less, require five times less stowed volume, and be more radiation resistant than state-of-the-art rigid panel arrays. Current polymer substrates for Copper-Indium-Gallium-DiSelenide (CIGS) thin film solar cells do not survive the high temperature processing necessary for fabricating the highest efficiency solar cells. Developed, fabricated, and tested high temperature			

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	silicone resin films suitable for CIGS thin film solar cell substrates. Demonstrated the deposition of CIGS solar cells on the high temperature polymers.			
(U)	In FY 2004: Further the development of silicone resin high temperature polymer substrates for Copper-Indium-Gallium-DiSelenide (CIGS) thin film solar cells for next-generation flexible, thin film solar arrays and develop monolithic integration of Copper-Indium-Gallium-DiSelenide (CIGS) solar cells on these substrates. Monolithic integration, which is enabled by these non-conductive substrates, reduces the touch labor necessary for interconnection of individual cells into solar arrays. Demonstrate the roll-to-roll deposition of CIGS solar cells on free-standing high temperature polymers and demonstrate large area monolithically-integrated CIGS modules.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	CONGRESSIONAL ADD: Integrated Control for Autonomous Space Systems (ICASS).	1.362	0.992	0.000
(U)	In FY 2003: Developed advanced attitude and dynamic control technologies for next generation spacecraft. These technologies provide unprecedented levels of control over dynamic subsystem response, precision pointing and target tracking. Designed an integrated controls architecture, which includes flight computer, an advanced suite of dynamic sensors, and real-time system identification software that can characterize the capability enhancements for operational space platforms.			
(U)	In FY 2004: Develop advanced attitude and dynamic control technologies for future space platforms to provide unprecedented levels of control over dynamic subsystem response, precision pointing, and target tracking. Fabricate the engineering models of integrated controls architecture designs, initiate laboratory validation and verification, and incorporate the engineering models into a spacecraft design.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	CONGRESSIONAL ADD: Elastic Memory Composites and Elastic Memory Composites Materials.	0.000	3.272	0.000
(U)	In FY 2003: Not Applicable.			
(U)	In FY 2004: Develop elastic memory composite material technologies for unconventional approaches in satellite component utility. These composite materials have unique properties that can be exploited to enable new types of spacecraft components and to enhance existing components. Design, build, and integrate elastic memory composite hinge hardware for possible on-orbit demonstration. Design and build a composite deploying gravity gradient boom as the primary attitude-stabilizing element for a satellite. Design and analyze large-scale rollout flexible solar array deployment mechanism.			
(U)	In FY 2005: Not Applicable.			
(U)				
(U)	CONGRESSIONAL ADD: Converted Silicon Carbide for High Performance Optic Structures.	0.000	1.487	0.000
(U)	In FY 2003: Not Applicable.			

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(U) In FY 2004: Explore the application of silicon carbide processes developed for the semi-conductor industry to the fabrication of large, lightweight, space optics. Design, analyze, fabricate, and test a silicone carbide mirror. Assess the potential cost, fabricating speed, and performance of mirrors fabricated from silicon carbide.
(U) In FY 2005: Not Applicable.
(U)
(U) CONGRESSIONAL ADD: Affordable Multi-Junction Solar Cells. 0.000 2.280 0.000
(U) In FY 2003: Not Applicable.
(U) In FY 2004: Develop a process for affordable production of single crystal Germanium (Ge) wafers, a key component of multi-junction solar cells on all Department of Defense satellites, comprising approximately half the cost of the entire cell. Develop a domestic source of Ge wafers encompassing the establishment of a pilot/bench operation, including demonstration of a crystal growth and wafer fabrication capability, a plan to recycle Ge metal, and a production scale-up plan. The bench operation will include wafer grinding, polishing, etching, characterization, and the establishment of quality control procedures.
(U) In FY 2005: Not Applicable.
(U) Total Cost 27.827 37.511 26.724

(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 0602102F, Materials.
(U) PE 0603311F, Ballistic Missile Technology.
(U) PE 0603401F, Advanced Spacecraft Technology.
(U) PE 0603500F, Multi-Disciplinary Advanced Development Space Technology.
(U) This project has been coordinated through the Reliance process to harmonize

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

efforts and eliminate
duplication.

(U) D. Acquisition Strategy

Not Applicable.