PE NUMBER: 0602500F
PE TITLE: MULTI-DISCIPLINARY SPACE TECH

# Exhibit R-2, RDT&E Budget Item Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

| | Cost ($ in Millions) | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Program Element (PE) Cost | 99.220 | 95.402 | 81.339 | 102.359 | 120.443 | 120.161 | 119.041 | 120.657 | Continuing | TBD |
| 5023 | Laser & Imaging Space Tech | 5.590 | 8.471 | 8.166 | 10.333 | 11.493 | 11.922 | 12.082 | 12.223 | Continuing | TBD |
| 5025 | Space Materials Development | 18.325 | 21.310 | 19.864 | 26.202 | 35.422 | 37.666 | 38.482 | 39.254 | Continuing | TBD |
| 5026 | Rocket Propulsion Component Tech | 51.862 | 49.521 | 41.212 | 45.839 | 45.427 | 47.642 | 48.594 | 48.778 | Continuing | TBD |
| 5027 | High Speed Airbreathing Prop Tech | 4.700 | 0.178 | 0.246 | 0.239 | 0.245 | 0.242 | 0.240 | 0.239 | Continuing | TBD |
| 5028 | Space Sensors, Photonics & RF Proc | 3.703 | 1.839 | 1.941 | 4.101 | 4.033 | 4.207 | 4.282 | 4.353 | Continuing | TBD |
| 5029 | Space Sensor & CM Tech | 8.064 | 5.167 | 1.111 | 4.482 | 6.419 | 5.691 | 5.783 | 5.863 | Continuing | TBD |
| 5081 | Space Antennas Tech | 1.034 | 1.394 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | Continuing | TBD |
| 5082 | Optical Networking Tech | 5.942 | 7.522 | 8.799 | 11.163 | 17.404 | 12.791 | 9.578 | 9.947 | Continuing | TBD |

Note: In FY 2004, efforts in Projects 5024 were terminated and efforts in Project 5030 were delayed until FY 2007 due to higher Air Force priorities. In FY 2006, efforts in Project 5081 move to Project 5082 and the Air Force increased emphasis on developing optical networks for space-based applications. In addition, changes continue due to adjustments based on recategorization of space unique tasks.

**(U) A. Mission Description and Budget Item Justification**

This program advances the technology base in multiple disciplines for future space applications with projects focusing on separate technology areas including: 1) laser and imaging space technologies, which develop concepts for advanced, very long-range optical systems and assess the vulnerability of satellites to the effects of high energy laser weapon systems; 2) space materials, which concentrate on the materials technology base for spacecraft and launch systems to improve affordability, maintainability, and performance; 3) rocket propulsion component technologies, which advance technology in liquid propulsion rocket engines, solid rocket motors, spacecraft and upper stage propulsion, ballistic missiles, and application of advanced materials for rockets to achieve revolutionary launch capabilities; 4) high-speed airbreathing propulsion technologies, which develop advanced and combined cycle engine technologies for revolutionary low-cost access to space; 5) space sensors, photonics, and radio frequency processes, which develop technologies to generate, control, process, receive, and transmit opto-electronic signals for space sensor applications; 6) space sensors and countermeasures technologies, which focus on generation, control, reception, and processing of electronic and electromagnetic signals for space sensor applications in intelligence, surveillance, reconnaissance, warning, electronic combat, and countermeasures; 7) applied space access vehicle technologies, which develop advanced concepts for affordable on-demand access to space; 8) lightweight satellite antenna technology and affordable antenna terminal technology for communications and surveillance; and 9) optical networking technology, which focuses on the space-based laser communications to provide the warfighter with unlimited communications to any place at any time. Note: In FY 2005, Congress added $1.0 million for Internet Protocol Commanding of Satellites, $5.0 million for ETIP-Engineering Tool Improvement Program, $1.7 million for Photonics Technology, and $4.0 million for Upperstage Engine Technology (USET). Additionally, $1.5 million was appropriated to this PE for Stable Articulating Backbone for Ultralight Radar Project; however, this has been moved to PE 0602204F, Aerospace Sensors, for execution. This program is in Budget Activity 2, Applied Research, since it develops and determines the technical feasibility and military utility of evolutionary and revolutionary technologies.

| Exhibit R-2, RDT&E Budget Item Justification | DATE February 2005 |
|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH |

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

| | | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|---|
| (U) | Previous President's Budget | 101.360 | 84.581 | 81.118 | 101.359 |
| (U) | Current PBR/President's Budget | 99.220 | 95.402 | 81.339 | 106.114 |
| (U) | Total Adjustments | -2.140 | 10.821 | | |
| (U) | Congressional Program Reductions | | -0.031 | | |
| | Congressional Rescissions | | -0.848 | | |
| | Congressional Increases | | 11.700 | | |
| | Reprogrammings | | | | |
| | SBIR/STTR Transfer | -2.140 | | | |

(U) Significant Program Changes:

Not Applicable.

C. Performance Metrics

(U) Under Development.

# Exhibit R-2a, RDT&E Project Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

PROJECT NUMBER AND TITLE: 5023 Laser & Imaging Space Tech

| Cost ($ in Millions) | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 5023 Laser & Imaging Space Tech | 5.590 | 8.471 | 8.166 | 10.333 | 11.493 | 11.922 | 12.082 | 12.223 | Continuing | TBD |
| Quantity of RDT&E Articles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

**(U) A. Mission Description and Budget Item Justification**

Develop advanced, long-range, optical technologies such as advanced beam control; beam acquisition, tracking, and pointing; adaptive optics; dual line-of-sight pointing; large, lightweight optics; and optical coatings that support relay mirror systems. Relay mirror systems can greatly extend the range of high-power laser weapons, as well as low-power imaging systems.

| **(U) B. Accomplishments/Planned Program ($ in Millions)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| (U) MAJOR THRUST: Develop advanced, long-range, optical technologies such as advanced beam control; beam acquisition, tracking, and pointing; adaptive optics; dual line-of-sight pointing; large, lightweight optics; and optical coatings that support relay mirror systems. Relay mirror systems can greatly extend the range of high-power laser weapons, as well as low-power imaging systems. Note: Increase in funding is due to greater emphasis on relay mirrors. | 2.804 | 6.406 | 6.211 | 8.347 |
| (U) In FY 2004: Developed technologies for lightweight primary mirrors applicable to bifocal relay mirrors. Investigated different solutions for spacecraft and optical control dynamics. | | | | |
| (U) In FY 2005: Develop dual line-of-sight pointing technology for tracking a satellite with a relay mirror. Develop miniature, micro electro-mechanical systems (MEMS), liquid crystals, and novel adaptive optic devices for both monolithic and phased array telescope systems that can be used for imaging and beam projection from space. | | | | |
| (U) In FY 2006: Investigate two-beam propagation techniques in support of a demonstration which tracks and illuminates a cruise missile through a relay mirror. Investigate critical advanced wavefront control devices for both monolithic and phased array imaging and beam projection from space. Develop selected devices to meet application requirements. | | | | |
| (U) In FY 2007: Begin investigations in support of a high-power demonstration to kill a missile through a relay mirror. Complete development of first generation advanced wavefront control device for imaging and beam projection. | | | | |
| (U) | | | | |
| (U) MAJOR THRUST: Assess the vulnerability of satellites to the effects of high-energy laser weapons and maintain and update catalogued satellites. | 1.812 | 2.065 | 1.955 | 1.986 |
| (U) In FY 2004: Developed finite state models for space systems that enabled rapid characterization of new launches and provided a better estimate of on orbit space systems capabilities for improved space situational awareness. | | | | |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5023 Laser & Imaging Space Tech** |

(U) In FY 2005: Update target system response databases for continued improvement of predictive avoidance analyses and provide data to U.S. Space Command for their performance of Laser Clearinghouse functions. Update previously completed assessments on catalogued satellites. Enhance and refine finite state modeling process and models for space systems that will enable rapid characterization of new launches and provide a better estimate of on-orbit space systems capabilities for improved space situational awareness. Update lethality assessment methodology by anchoring modeling tools to empirical data. Perform finite state modeling of laser targets to better understand vulnerabilities and identify indicators of battle damage assessment. Incorporate improved algorithms and hardware for rapidly characterizing space objects and new launches into current data fusion workstations needed for satellite assessments and for the space situational awareness mission.

(U) In FY 2006: Assess the survivability and vulnerability of aerospace systems to the effects of high-energy laser and other directed energy systems. Update response databases for continued improvement of predictive avoidance analyses and provide data to U.S. Strategic Command for the performance of Laser Clearinghouse functions. Update previously completed assessments on catalogued satellites. Enhance and refine finite state modeling process, physical, and functional models for space systems that will enable rapid characterization of new launches and provide a better estimate of on orbit space systems capabilities for improved space situational awareness. Continue to update assessment methodology by anchoring modeling tools to empirical data. Incorporate improved algorithms and hardware for rapidly characterizing space objects and new launches into current data fusion workstations needed for satellite assessments and for the space situational awareness mission.

(U) In FY 2007: Develop and apply improved algorithms and hardware for satellite characterization and vulnerability assessment. Continue to update assessment methodology by anchoring modeling tools to empirical data, including results of laser illumination, tracking, and compensated imaging data. Assess the survivability and vulnerability of aerospace systems to the effects of directed energy weapons. Update response databases for continued improvement of predictive avoidance analyses and provide data to U.S. Strategic Command for the performance of Laser Clearinghouse functions.

(U)

| | | | | |
|---|---|---|---|---|
| (U) CONGRESSIONAL ADD: Starfire Optical Range Coating Facility. | 0.974 | 0.000 | 0.000 | 0.000 |

(U) In FY 2004: Developed a mirror recoating chamber for the Starfire Optical Range 3.5 meter telescope primary mirror, with the capability to coat other large mirrors as needed. Designed and built the equipment needed for washing, stripping, and vapor deposition aluminum coating of two to four meter diameter mirrors and integrated with large mirror coating room.

(U) In FY 2005: Not Applicable.

(U) In FY 2006: Not Applicable.

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5023 Laser & Imaging Space Tech |

(U) In FY 2007: Not Applicable.

| | | | | |
|---|---|---|---|---|
| (U) Total Cost | 5.590 | 8.471 | 8.166 | 10.333 |

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

| | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| (U) Related Activities: | | | | | | | | | | |
| (U) PE 0602605F, Directed Energy Technology. | | | | | | | | | | |
| (U) PE 0603444F, Maui Space Surveillance Systems. | | | | | | | | | | |
| (U) PE 0603500F, Multi-Disciplinary Adv Dev Space Technology. | | | | | | | | | | |
| (U) PE 0603605F, Advanced Weapons Technology. | | | | | | | | | | |
| (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication. | | | | | | | | | | |

**(U) D. Acquisition Strategy**

Not Applicable.

# Exhibit R-2a, RDT&E Project Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

PROJECT NUMBER AND TITLE: 5025 Space Materials Development

| Cost ($ in Millions) | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 5025 Space Materials Development | 18.325 | 21.310 | 19.864 | 26.202 | 35.422 | 37.666 | 38.482 | 39.254 | Continuing | TBD |
| Quantity of RDT&E Articles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

**(U) A. Mission Description and Budget Item Justification**

This project develops the materials and processing technology base for spacecraft and launch systems to improve affordability, maintainability, and performance of current and future Air Force space systems. Families of affordable lightweight materials are being developed, including metals, polymers, ceramics, metallic composites, and nonmetallic composites to provide new capabilities for spacecraft, ballistic missile, and propulsion systems to meet the future space requirements. Rocket propulsion materials development in this project supports the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program. Advanced high-temperature protection materials are being developed that are affordable, lightweight, dimensionally stable, thermally conductive, and/or ablation and erosion resistant to meet space and ballistic missile requirements. Materials technologies are also being developed to enable surveillance and terrestrial situational awareness systems and subsystems for space and ballistic missile applications.

| **(U) B. Accomplishments/Planned Program ($ in Millions)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| (U) MAJOR THRUST: Develop materials and processes to dramatically improve performance, durability, and cost of rocket propulsion systems. | 9.803 | 11.176 | 11.197 | 11.278 |

(U) In FY 2004: Developed candidate materials and improved processing capabilities to ensure consistent material characteristics for high-speed turbopump housings, ducts, valves, solid rocket casings, insulation, nozzle throats, and spacecraft propulsion. Evaluated high-temperature metals, ceramics, and composite materials by fabricating test articles with representative geometry to validate material characteristics and processing capabilities for solid rocket nozzles, throats, and spacecraft propulsion. Established materials database and provided predictive modeling capability to anticipate materials performance and model life-cycle behavior of materials in a rocket propulsion environment. Identified new candidate materials suitable for spacecraft and rocket propulsion environments, such as thrust chambers, nozzles, and propellant catalysts.

(U) In FY 2005: Evaluate materials in an appropriate test environment for high-speed turbopump housings, ducts, valves, solid rocket casings, insulation, nozzle throats, and spacecraft propulsion. Establish performance of test articles with representative geometry using high-temperature metals, ceramics, and composite materials to validate material characteristics and processing capabilities for solid rocket nozzles, throats, and spacecraft propulsion. Evaluate engine component suitability using direct replacement of materials or enabling new design based on established material properties. Evaluate materials for pursuing applications, such as thrust chambers, nozzles, and propellant catalysts at high-temperature, high-pressure, and cryogenic environments.

(U) In FY 2006: Evaluate suitability of materials for high-speed turbopumps, ducts, valves, solid rocket

| Exhibit R-2a, RDT&E Project Justification | | | DATE: February 2005 |
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| BUDGET ACTIVITY: 02 Applied Research | PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE: 5025 Space Materials Development | |

| | | | | | |
|---|---|---|---|---|---|
| | casings, insulation, nozzle throats, and spacecraft propulsion applications. Fabricate subscale articles and test in representative rocket engine environment to validate materials performance. Analyze material behavior in rocket combustion environment for solid rocket nozzles, exit cones, throats, and spacecraft propulsion components. Validate materials performance goals for direct replacement of materials. Evaluate processes for scale-up from coupon-level testing to more complex shapes and sizes. Demonstrate innovative concepts and technologies that could enable new engine designs. Characterize material candidates, analyze material performance, and identify ways to improve thrust chambers, nozzles, and catalysts. | | | | |
| (U) | In FY 2007: Develop new candidate materials and improved processing techniques to ensure more consistent material characteristics to meet the next level of performance goals for high-speed turbopump housings and turbines, ducts, valves, solid rocket casings, insulation, and nozzle throats. Evaluate performance of subscale test components in representative rocket engine environment. Continue analysis of material behavior in rocket combustion environment. Demonstrate innovative high-temperature metal, ceramic, and composite material candidates for solid rocket nozzles, exit cones, throats, and spacecraft propulsion components. Validate material models for direct replacement of materials. Scale-up testing from coupon level to more complex shapes and sizes. Fabricate subscale components. Incorporate innovative materials and concepts on demonstrator engines. Identify materials characteristics required to meet advanced performance and cost goals. Improve and optimize selected materials, test sub-elements, and sub-components for thrust chambers, nozzles, and catalysts. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop nanostructured materials technology for insertion into structures, propulsion, and subsystems applications such as rocket engine components and cryogenic components and structures to enable lighter weights, better performance, and lower costs. Note: In FY 2006 only, effort slipped due to higher priorities. In FY 2007, increase in funding is due to greater emphasis on the nano-photonic materials efforts. | 0.200 | 1.100 | 0.000 | 6.162 |
| (U) | In FY 2004: Investigated nanoparticle and nanostructured fabrication, characterization, processing techniques, and models for the efficient, low-cost assembly of nanomaterials. | | | | |
| (U) | In FY 2005: Develop nanoparticle and nanostructured fabrication, characterization, processing techniques, and models for the efficient, low-cost assembly of nanomaterials. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Initiate research in nano-photonic materials for applications in very high bandwidth communications and modulators, laser communications, and radar. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop affordable, advanced structural and non-structural materials and processing | 5.422 | 6.890 | 7.094 | 6.778 |

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|---|---|---|
| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5025 Space Materials Development** |

technologies for Air Force space applications.

(U) In FY 2004: Matured processing methods for the metallic materials that are expected to be used for lightweight, high-strength components in future space vehicles. Developed and fabricated high-temperature metallic gamma-titanium-aluminide technologies for reusable access to space vehicles. Developed advanced and reproducible joining processes for large metallic cryotanks. Developed analytical understanding of the behavior of composites in liquid oxygen environments and in a simulated space environment facility. Developed novel high-temperature protection system concepts for high-Mach, reentry, and access to space vehicles. Integrated carbon foam materials into space thermal management applications. Integrated foams into heat-pipe efficient radiator applications. Evaluated high-temperature organic matrix composites for tanks and structures for space access and launch vehicle applications. Fabricated laboratory-level demonstrations of optically tailorable active thermal control coatings with controlled heat dissipation for spacecraft thermal control and three-fold increase in service life. Developed baseline effects of the space environment on thermal control coatings, space lubricants, and other organic/inorganic space materials. Identified configurations suitable for use of non-oxide ceramic composites for standoff high temperature protection systems. Developed test procedures to validate candidate space materials. Developed repair processes for non-metallic space materials.

(U) In FY 2005: Establish performance of high-temperature metallic, high-temperature protection systems using gamma-titanium-aluminide as an external skin for reusable access to space vehicles. Assess aluminum-lithium metallic cryotank materials for multiple mission access to space. Explore candidate metallic systems for thin gage structures for component operation in robust high-temperature, long duration cruise or access to space environments. Expand experimental data and analytical results of liquid oxygen compatibility research. Continue to derive a more representative test series for composite materials. Develop subscale novel high-temperature protection systems in conditions that simulate representative reentry and high-Mach vehicles flight profiles. Initiate testing of candidate space materials to validate test procedures. Mature all-composite heat-pipe radiators for Air Force space systems. Explore oxidation-protected carbon-carbon materials. Establish capability of optically tailorable active thermal control coatings with controlled heat dissipation to provide three-fold increase in service life for spacecraft thermal control. Continue developing and evaluating baseline effects of the space environment on thermal control coatings, space lubricants, and other organic/inorganic space materials. Explore wear-resistant materials, lubricants, and Micro-Electro-Mechanical System (MEMS) devices for moving mechanical assemblies on spacecraft. Develop non-oxide ceramic composites for stand-off high temperature protection systems. Evaluate rapid inspection techniques for both advanced ceramic tile and stand-off high-temperature protection system materials. Assess techniques to validate candidate space materials performance. Establish suitability of repair processes for non-metallic space materials.

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| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5025 Space Materials Development** |

(U) In FY 2006: Develop candidate metallic systems for thin gage structures for component operation in robust high-temperature, long duration cruise or access to space environments. Refine analytical methods to understand behavior of materials in cryogenic environments and analyze liquid oxygen (LOX) compatibility research results through integrated technical working groups with industry and National Aeronautics and Space Administration (NASA). Develop subscale high-temperature protection systems for leading edges, nosetips, and aeroshells for expendable and reusable high-speed vehicle applications. Demonstrate oxidation-protected carbon-carbon materials in environments relevant to high-speed vehicle applications. Develop advanced composite technologies for thermal management and dimensionally stable structural space applications. Develop wear-resistant materials, lubricants, and MEMS devices for moving mechanical assemblies on spacecraft. Evaluate candidate space materials and collect critical data to facilitate materials transition.

(U) In FY 2007: Validate initial material design concept of candidate metallic systems for thin gage structures for component operation in robust high-temperature, long duration cruise or access to space environments. Continue analysis of research results and develop knowledge base on LOX compatibility with NASA and industry. Evaluate large integrated concepts using composite materials in cryogenic environments and provide expertise for design and assessment of structural cryogenic tanks. Demonstrate high-temperature protection systems for expendable and reusable high-speed vehicle applications in collaboration with industry. Validate oxidation protection schemes for carbon-carbon materials for high-speed vehicle applications. Develop multifunctional nano-tailored composite technologies for space system capabilities and evaluate enhancements obtained. Continue to develop wear-resistant materials, lubricants, and MEMS devices for moving mechanical assemblies on spacecraft. Continue to evaluate candidate space materials and collect critical data to facilitate materials transition.

(U)

| | | | | |
|---|---|---|---|---|
| (U) MAJOR THRUST: Develop materials and materials processing technologies to enable improved performance and affordability of surveillance, tracking, targeting, and situational awareness systems. | 2.900 | 2.144 | 1.573 | 1.984 |

(U) In FY 2004: Identified higher performance materials, including optical nanocomposites and exotic ferroelectronics, for advanced optical architecture in phased array radar and satellite-to-satellite data links. Scaled-up very long wavelength, alternative infrared detector materials to areas suitable for the fabrication of staring focal plane arrays.

(U) In FY 2005: Develop electro-optic polymers for optical communications, data links, and radio frequency (RF) system control architectures. Demonstrate the detection performance of very long wavelength alternative materials operating at 40 Kelvin. Investigate materials and process technologies capable of providing solutions for mixed-mode (optical and RF) communications apertures.

(U) In FY 2006: Demonstrate electro-optic polymers for optical communications, data links, and RF system

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| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5025 Space Materials Development** |

control architectures. Explore processes to allow advanced materials design and architecture development for very long wavelength alternative materials operating at 40 Kelvin. Develop materials and materials process technologies for application in combined optical and RF communication system apertures.

(U) In FY 2007: Initiate development of nano-photonic materials for high performance optoelectronic devices for optical communications and system control architectures. Validate processes and develop process control methodology to enable very long wavelength infrared detection. Continue to develop suitable materials and materials process technologies for application in combined optical and RF communication system apertures.

| | | | | | |
|---|---|---|---|---|---|
| (U) Total Cost | 18.325 | 21.310 | 19.864 | 26.202 | |

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

| | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| (U) Related Activities: | | | | | | | | | | |
| (U) PE 0602102F, Materials. PE 0603112F, Advanced Materials for Weapon Systems. | | | | | | | | | | |
| (U) PE 0603500F, Multi-Disciplinary Advanced Development Space 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 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

PROJECT NUMBER AND TITLE: 5026 Rocket Propulsion Component Tech

| Cost ($ in Millions) | | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5026 | Rocket Propulsion Component Tech | 51.862 | 49.521 | 41.212 | 45.839 | 45.427 | 47.642 | 48.594 | 48.778 | Continuing | TBD |
| | Quantity of RDT&E Articles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

**(U) A. Mission Description and Budget Item Justification**

This project develops advances in rocket propulsion technologies for space access, space maneuver, and ballistic missiles. Analytical and experimental areas of emphasis are propellants, propellant management, combustion, rocket material applications, Technology for Sustainment of Strategic Systems (TSSS) Phase 1, and novel space propulsion concepts. Technologies of interest will improve reliability, performance, survivability, affordability, and environmental compatibility of future space and missile launch subsystems. Technologies are developed to reduce the weight and cost of components using new materials and improved designs and manufacturing techniques. All efforts in this project contribute to the IHPRPT program, a joint Department of Defense, NASA, and industry effort to focus rocket propulsion technology on national needs.

| **(U) B. Accomplishments/Planned Program ($ in Millions)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| (U) MAJOR THRUST: Develop, characterize, and test advanced hydrocarbons, energetics, and reduced-toxicity monopropellants to increase space launch payload capability and refine new propellants synthesis methods. Efforts include evaluation and development of reduced-toxicity ionic salt, high-energy-density oxidizers, nano-materials, catalyst, and polymeric binders; determining optimized paths for incorporating these materials into propellants; and for selected propellants perform laboratory and demonstrator engine evaluations. Efforts seek monopropellants with performance equivalent to bipropellants that reduce the cost of space access and space operations. Phases are referring to the IHPRPT program phases. | 2.753 | 3.941 | 3.528 | 3.167 |

(U) In FY 2004: Began development of advanced catalysts for new monopropellant formulations. Downselected and began scale-up of promising high energy-density materials candidates. Evaluated selected propellants in advanced combustion devices to determine materials compatibility and performance. Formulated propellant ingredients for IHPRPT Phase III solid propellant developments and began transition to propellant formulation. Studied ablation effects on laser-propelled lightcraft fuels and fuel systems. Modeled and explored advanced propulsion concepts with enhanced performance and reliability such as rocket-based combined cycle engines.

(U) In FY 2005: Further downselect and continue scaling-up promising high energy-density materials candidates. Evaluate scaled-up and new selected propellants in advanced combustion devices to determine materials compatibility and performance, and address ballistic property concerns. Continue maturing solid propellants ingredients into Phase III solid propellant formulations. Initiate efforts to address ablation effects on laser-propelled lightcraft fuel and fuel system. Continue to model and analyze

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
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| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5026 Rocket Propulsion Component Tech** |

advanced propulsion concepts with enhanced performance and reliability such as rocket-based combined cycle engines.

(U) In FY 2006: Further downselect and continue scaling-up promising high energy-density materials candidates. Evaluate scaled-up and new selected propellants in advanced combustion devices to determine materials compatibility and performance and prepare for large-scale motor tests. Complete initial solid propellants ingredients incorporation into Phase III solid propellant formulations. Complete efforts to address ablation effects on laser-propelled lightcraft fuel and fuel system. Continue to model and analyze advanced propulsion concepts with enhanced performance and reliability such as rocket-based combined cycle engines.

(U) In FY 2007: Further downselect and continue scaling-up promising high energy-density materials candidates. Evaluate scaled-up and new selected propellants in advanced combustion devices to determine materials compatibility and performance to include supporting large-scale motor tests. Continue to model and analyze advanced propulsion concepts with enhanced performance and reliability such as rocket-based combined cycle engines.

(U)

| | | | | |
|---|---|---|---|---|
| (U) MAJOR THRUST: Develop advanced liquid engine combustion technology for improved performance, while preserving chamber lifetime and reliability needs for engine uses in heavy lift space vehicles. Efforts include modeling and analyzing advanced propulsion concepts with enhanced performance and reliability such as aerovehicles and potential launch systems. Phases are referring to the IHPRPT program phases. Note: The FY 2004 start of hydrocarbon combustion instability efforts was delayed until FY 2006; the associated funding was shifted to support improvements to advanced cryogenic upper stage technologies. In FY 2005, increase in funding is due to greater emphasis on the upper stage technology efforts. | 3.647 | 7.200 | 8.206 | 7.824 |

(U) In FY 2004: Characterized, studied, and evaluated gas-centered swirl injector performance to ensure chamber/injector compatibility and prevent damage to Phase II hydrocarbon boost engine. Developed, analyzed, and modeled advanced combustion devices and injectors compatible with new energetic propellants. Initiated development and early transition opportunities for near-term advanced hydrocarbon fuels for scale-up and sub-scale test.

(U) In FY 2005: Complete characterizing, studying, and evaluating gas-centered swirl injector performance for hydrocarbon boost engine and increase emphasis on chamber/injector compatibility for upper stage engines. Initiate advanced multi-phase modeling and subscale combustion evaluation of new high density refined and advanced hydrocarbon fuels to meet Phase II goals.

(U) In FY 2006: Initiate characterization, studies, and evaluations of shear coaxial injector performance to ensure chamber/injector compatibility and prevent damage to upper stage engines. Develop experiments

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5026 Rocket Propulsion Component Tech |

| | | | | | |
|---|---|---|---|---|---|
| | to enhance the thermal management of upper stage engines for better performance, chamber life, and reliability. Initiate analysis and test to characterize causes and issues that lead to combustion instability in hydrocarbon fueled liquid rocket engines reducing the need for conducting large numbers of costly full-scale component and engine tests. Develop advanced synthetic hydrocarbon fuels to meet Phase II goals. | | | | |
| (U) | In FY 2007: Continue to characterize, study, and evaluate shear coaxial injector performance to ensure chamber/injector compatibility and prevent damage to upper stage engines. Continue to develop, analyze, and transition advanced combustion device technology, including injectors and chambers suitable for advanced synthetic hydrocarbon fuels capable of meeting or exceeding the Phase III goals. Develop improved understanding of fundamental combustion and fluid flow/heat transfer processes leading to new methodologies for thermal management, scaling, and combustion instabilities in hydrocarbon fueled liquid rocket engines, reducing the need for conducting large numbers of costly full-scale component and engine tests. Develop, scale-up, and transition new energetic advanced hydrocarbon fuels and additives for rocket propulsion, including space storable high energy, non-toxic fuels. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop advanced material applications for lightweight components and material property enhancements for use in advanced combustion devices and propulsion systems for current and future rocket propulsion systems. | 3.108 | 4.009 | 5.324 | 4.844 |
| (U) | In FY 2004: Developed advanced ablative components with nano-reinforced, hybrid polymers. Characterized and developed new processes for high temperature polymers utilizing nanomaterials and carbon-carbon materials to improve process and structural density. Developed advanced material components for use with high-energy propellants. Commenced transition of advanced high temperature material components to reduce system weight and cost, and increase performance. Initiated exploration of the use of nanocomposites for liquid rocket engine tanks. | | | | |
| (U) | In FY 2005: Continue additional development of advanced ablatives for use in low-cost, sprayable processing. Continue to characterize and develop new high temperature polymers incorporating synergistic effects of multiple nanomaterials and carbon-carbon materials to reduce cost and processing time. Continue developing new advanced materials for use with high-energy propellants. Continue transition of specific advanced high temperature materials to air and space systems to reduce system weight and cost, and increase performance. Continue to explore using nanocomposites for liquid rocket engine tanks with multi-functional capability (lightweight, inert, in situ passivation). | | | | |
| (U) | In FY 2006: Develop advanced, recyclable, ablative components using nano-reinforced hybrid polymers that are two times better than previously developed materials. Continue to characterize and develop | | | | |

| Exhibit R-2a, RDT&E Project Justification | | | DATE February 2005 |
|---|---|---|---|
| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5026 Rocket Propulsion Component Tech** | |

| | | | | | |
|---|---|---|---|---|---|
| | processing technologies to improve nano-reinforced high temperature polymers and carbon-carbon materials. Continue developing new advanced materials for use with high-energy propellants. Complete transition of specific advanced high temperature materials to air and space systems to reduce system weight and cost, and increase performance. Develop processing methodology for using nanocomposites for liquid rocket engine tanks. | | | | |
| (U) | In FY 2007: Continue developing new advanced ablative components using hybrid polymers. Continue to characterize and finalize processing parameters of new nano-reinforced high temperature polymers and scale-up processing of carbon-carbon materials. Continue developing new advanced materials for use with high-energy propellants. Continue to explore using nanocomposites for liquid rocket engine tanks and optimize processing technology using multifunctional nanomaterials. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop propulsion component technologies for reliable, safe, and low-cost boost systems. Note: In FY 2005, these efforts were moved to the "advanced liquid engine technologies" major thrust in this Project. | 2.316 | 0.000 | 0.000 | 0.000 |
| (U) | In FY 2004: Completed testing a single stage hydrogen turbopump for advanced cryogenic boost engines. Completed development of components for hybrid propulsion technologies for space boosters and air launched missiles. Advanced hydrocarbon fuel characterization test rig development. | | | | |
| (U) | In FY 2005: Not Applicable. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop lightweight combustion devices and nozzle technologies for liquid rocket engines. Note: In FY 2005, these efforts were moved to the "advanced liquid engine technologies" major thrust in this Project. | 23.203 | 0.000 | 0.000 | 0.000 |
| (U) | In FY 2004: Furthered the development of an advanced lightweight altitude-compensating nozzle. Furthered design studies for advanced liquid oxygen and liquid hydrogen turbopumps for the next phase of advanced upper stage engines. | | | | |
| (U) | In FY 2005: Not Applicable. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop advanced liquid engine technologies for improved performance, while increasing life and reliability needs for engine uses in expendable and reusable launch vehicles. Note: Prior to FY 2005, these activities were conducted under other efforts earlier in this Project. | 0.000 | 20.533 | 19.800 | 24.147 |

| Exhibit R-2a, RDT&E Project Justification | | | DATE: February 2005 |
|---|---|---|---|
| BUDGET ACTIVITY: 02 Applied Research | PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE: 5026 Rocket Propulsion Component Tech | |

| | | | | | |
|---|---|---|---|---|---|
| (U) | In FY 2004: Not Applicable. | | | | |
| (U) | In FY 2005: Complete initial assessment and continue tool improvement for advanced cryogenic upper stage technologies - turbopumps and thrust chambers. Evaluate first set of potential hydrocarbon fuels and adjust/modify/develop fuel characterization test rig. Complete development of first of two concepts for new lightweight nozzles for liquid rocket engines. | | | | |
| (U) | In FY 2006: Advance modeling and simulation tool development for advanced cryogenic liquid rocket upper stage technologies. Commence hardware design for advanced cryogenic upper stage technologies - turbopumps and thrust chambers. Evaluate second set of potential hydrocarbon fuels and adjust/modify/ develop fuel characterization test rig. Continue development of second concept for lightweight nozzles for liquid rocket engines. | | | | |
| (U) | In FY 2007: Continue development of advanced cryogenic upper stage technologies - turbopumps and thrust chambers. Evaluate third set of potential hydrocarbon fuels and adjust/modify/ develop fuel characterization test rig. Complete development of second concept for lightweight nozzles for liquid rocket engines. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop missile propulsion, aging, and surveillance technology for solid rocket systems for Intercontinental Ballistic Missile to include testing missile propulsion technology and Post Boost Control Systems (PBCS). Efforts support Technology for Sustainment of Strategic Systems program - Phase I. Note: After FY 2004, these efforts were moved to Advanced Technology Development efforts in PE 0603500F. | 0.500 | 0.000 | 0.000 | 0.000 |
| (U) | In FY 2004: Developed and fabricated components for demonstrations of advanced full-scale, flight-like PBCS. | | | | |
| (U) | In FY 2005: Not Applicable. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop solar electric, solar thermal, chemical, and advanced propulsion technologies for stationkeeping, repositioning, and orbit transfer for large communication satellites, microsatellites, and satellite constellations. Phases are referring to the IHPRPT program phases. | 4.944 | 4.917 | 4.354 | 5.857 |
| (U) | In FY 2004: Commenced development of monopropellant thruster component technologies for chemical-based space propulsion catalyst. Completed fabrication of an extended life Hall thruster demonstrator (Phase II). Developed and fabricated subsystems for the Phase II plasma thrusters for microsatellites propulsion systems. Completed development of solar thrusters and concentrators for future orbital transfer vehicles. Furthered development and test of a controlled solid propellant. | | | | |

| Exhibit R-2a, RDT&E Project Justification | | | DATE February 2005 |
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| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5026 Rocket Propulsion Component Tech** | |

| | | | | | |
|---|---|---|---|---|---|
| (U) | In FY 2005: Continue development of monopropellant thruster component technologies for chemical-based space propulsion - catalyst and thrust chamber. Initiate Hall thruster Phase II system lifetest and commence Phase III development efforts. Integrate components and initiate Phase II plasma thruster lifetests for microsatellites propulsion systems. Continue development and test of a controlled solid propellant. | | | | |
| (U) | In FY 2006: Complete initial development and test of monopropellant thruster component technologies for chemical-based space propulsion. Complete Hall thruster Phase II lifetest and continue Phase III development efforts. Complete Phase II lifetest and begin evaluating Phase III plasma thrusters for microsatellites propulsion systems. Complete development and test of a controlled solid propellant. | | | | |
| (U) | In FY 2007: Continue Hall thruster Phase III development efforts. Continue evaluating Phase III plasma thrusters for microsatellites propulsion systems. Initiate advanced bi-propellant technology developments for satellite thrusters. Initiate advanced hybrid propulsion concept for satellites. | | | | |
| (U) | | | | | |
| (U) | CONGRESSIONAL ADD: Launch Vehicles Engine Project. | 0.974 | 0.000 | 0.000 | 0.000 |
| (U) | In FY 2004: Conducted studies and developed hardware for proof of concept for a low-cost launch vehicle engine with 400,000 pounds of thrust using liquid oxygen and hydrogen as propellants. | | | | |
| (U) | In FY 2005: Not Applicable. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | CONGRESSIONAL ADD: Jet and Rocket Engine Test Site. Note: In FY 2005, Congress continued this program in PE 0602203F. | 10.417 | 0.000 | 0.000 | 0.000 |
| (U) | In FY 2004: Furthered upgrades to the rocket engine test stands at the former Norton Air Force Base in San Bernardino. Expanded testing to include thermal and vibrational test capability for satellite systems. | | | | |
| (U) | In FY 2005: Not Applicable. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | CONGRESSIONAL ADD: ETIP-Engineering Tool Improvement Program. Note: Efforts expand upon activities in a FY 2004 Congressional Add in PE 0602203. | 0.000 | 4.956 | 0.000 | 0.000 |
| (U) | In FY 2004: Not Applicable. | | | | |
| (U) | In FY 2005: Improve existing and develop new modeling and simulation tools to address spacecraft component interactions and solid rocket motor heat transfer, insulation performance, plume dispersion, and liquid rocket engine power balance. Develop the integrated reusable launch vehicle analysis tool, | | | | |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
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| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5026 Rocket Propulsion Component Tech |

| | | | | | |
|---|---|---|---|---|---|
| | which will be used to determine weight, size and performance of future two-stage-to-orbit vehicle concepts. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | CONGRESSIONAL ADD: Upperstage Engine Technology (USET). | 0.000 | 3.965 | 0.000 | 0.000 |
| (U) | In FY 2004: Not Applicable. | | | | |
| (U) | In FY 2005: Provide for additional validation hardware and risk reduction to existing core effort to develop advanced modeling and simulation design tools for liquid rocket engines. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | Total Cost | 51.862 | 49.521 | 41.212 | 45.839 |

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

| | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| (U) Related Activities: | | | | | | | | | | |
| (U) PE 0601102F, Defense Research Sciences. | | | | | | | | | | |
| (U) PE 0602114N, Power Projection Applied Research. | | | | | | | | | | |
| (U) PE 0602203F, Aerospace Propulsion. | | | | | | | | | | |
| (U) PE 0602303A, Missile Technology. | | | | | | | | | | |
| (U) PE 0602805F, Dual Use Science and Technology. | | | | | | | | | | |
| (U) PE 0603216F, Aerospace Propulsion and Power Technology. | | | | | | | | | | |
| (U) PE 0603500F, Multi-Disciplinary Adv Dev Space Technology. | | | | | | | | | | |
| (U) This project has been | | | | | | | | | | |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5026 Rocket Propulsion Component Tech |

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

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 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

PROJECT NUMBER AND TITLE: 5027 High Speed Airbreathing Prop Tech

| Cost ($ in Millions) | | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5027 | High Speed Airbreathing Prop Tech | 4.700 | 0.178 | 0.246 | 0.239 | 0.245 | 0.242 | 0.240 | 0.239 | Continuing | TBD |
| | Quantity of RDT&E Articles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

**(U) A. Mission Description and Budget Item Justification**

This project develops revolutionary, airbreathing, hypersonic propulsion technology options to enable affordable, on demand access to space for the Air Force. The short-term focus is on hydrocarbon fueled engines capable of operating over a broad range of flight Mach numbers and longer term focus will be on hydrogen fueled scramjet powered engines that can enable the higher Mach numbers to achieve access to space. Technologies developed under this program enable capabilities of interest to both the Department of Defense and the NASA. Efforts include modeling and simulation, proof of concept tests of critical components, advanced component development, and ground-based tests.

| (U) B. Accomplishments/Planned Program ($ in Millions) | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| (U) MAJOR THRUST: Conduct assessments, system design trades, and simulations to integrate combined cycle engines (CCEs) and advanced cycle airbreathing hypersonic propulsion technologies in support of the development of affordable, on-demand access to space vehicles to meet future warfighter needs. | 0.568 | 0.178 | 0.246 | 0.239 |
| (U) In FY 2004: Conducted system trade studies to determine military payoff and establish component technology goals. Defined component and engine performance objectives to enable development of affordable hypersonic CCEs. | | | | |
| (U) In FY 2005: Conduct system trade studies to determine military payoff and establish component technology goals. Continue to define new component and engine performance objectives to enable development of affordable hypersonic CCEs. | | | | |
| (U) In FY 2006: Conduct system trade studies to determine military payoff and establish component technology goals. Continue to define new component and engine performance objectives to enable development of affordable hypersonic CCEs. | | | | |
| (U) In FY 2007: Conduct system trade studies to determine military payoff and establish component technology goals. Continue to define new component and engine performance objectives to enable development of affordable hypersonic CCEs. | | | | |
| (U) | | | | |
| (U) MAJOR THRUST: Develop robust hydrocarbon fueled scramjet engine components and technologies with improved performance, operability, durability, and scalability for affordable, on-demand access to space vehicles. Note: The FY 2004 internal flame stabilization effort was broadened to support risk mitigation for the Air Force's refocused hypersonic activities resulting from the reduction of the NASA hypersonic effort. In FY 2005, these activities were moved to PE 0602203F, Project 3012 to consolidate all 6.2 scramjet development efforts. | 4.132 | 0.000 | 0.000 | 0.000 |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5027 High Speed Airbreathing Prop Tech** |

(U) In FY 2004: Completed initial feasibility assessments of variable geometry devices to increase scramjet operating range (Mach 3 to Mach 8+) to provide robust options for CCEs. Further developed advanced engine components to improve operability, scalability, and structural durability for reusable applications. Assessed alternate scramjet flowpath configurations to improve engine operability and structural efficiency necessary for engine development for reusable applications. Demonstrated advanced ignition systems for scramjets. Conducted assessment of current structural concepts and identified life-limiting factors and initiated development of multi-use components. Initiated support for the development of flight test engine components.

(U) In FY 2005: Not Applicable.

(U) In FY 2006: Not Applicable.

(U) In FY 2007: Not Applicable.

(U)

(U)

| | | | | |
|---|---|---|---|---|
| (U) Total Cost | 4.700 | 0.178 | 0.246 | 0.239 |

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

| | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| (U) Related Activities: | | | | | | | | | | |
| (U) PE 0601102F, Defense Research Sciences. | | | | | | | | | | |
| (U) PE 0602201F, Aerospace Flight Dynamics. | | | | | | | | | | |
| (U) PE 0602203F, Aerospace Propulsion. | | | | | | | | | | |
| (U) PE 0602602F, Conventional Munitions. | | | | | | | | | | |
| (U) PE 0602702E, Tactical Technology. | | | | | | | | | | |
| (U) PE 0603111F, Aerospace Structures. | | | | | | | | | | |
| (U) PE 0603216F, Aerospace Propulsion and Power Technology. | | | | | | | | | | |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
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| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5027 High Speed Airbreathing Prop Tech** |

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

(U) PE 0603601F, Conventional Weapons Technology.

(U) Program is reported to/coordinated by the Joint Army/Navy/NASA/Air Force (JANNAF) Executive Committee.

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

**(U) D. Acquisition Strategy**

Not Applicable.

# Exhibit R-2a, RDT&E Project Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

PROJECT NUMBER AND TITLE: 5028 Space Sensors, Photonics & RF Proc

| | Cost ($ in Millions) | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5028 | Space Sensors, Photonics & RF Proc | 3.703 | 1.839 | 1.941 | 4.101 | 4.033 | 4.207 | 4.282 | 4.353 | Continuing | TBD |
| | Quantity of RDT&E Articles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

**(U) A. Mission Description and Budget Item Justification**

This project focuses on developing methods of generating, controlling, receiving, transmitting, and processing photonic, optical, and opto-electronic (mixed) signals for RF space sensor applications. The enabling technologies will be used for intelligence, surveillance, reconnaissance, electronic warfare, and precision engagement sensors based in space. The project aims to demonstrate significantly improved military space sensors of smaller size, lower weight, lower cost, lower power dissipation, higher reliability, and improved performance. This project also develops and assesses multi-dimensional adaptive techniques in radar technology for affordable and reliable space surveillance and reconnaissance systems.

| **(U) B. Accomplishments/Planned Program ($ in Millions)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| (U) MAJOR THRUST: Design and develop high performance integrated photonic technologies for use in space. Note: In FY 2006, effort moves to advanced photonic component technology for space-based sensors thrust in this Project. | 0.560 | 0.250 | 0.000 | 0.000 |
| (U) In FY 2004: Fabricated and evaluated high performance integrated photonic technology link, interconnect, and switching components and subsystems for wideband RF phased array antenna beamforming and control, and for high data rate space sensors and communication systems. | | | | |
| (U) In FY 2005: Test and evaluate high performance integrated photonic technology link, interconnect, and switching components and subsystems for wideband radio frequency phased array antenna beamforming/control, and for high data rate space sensors and communication systems. | | | | |
| (U) In FY 2006: Not Applicable. | | | | |
| (U) In FY 2007: Not Applicable. | | | | |
| (U) | | | | |
| (U) MAJOR THRUST: Design and develop efficient, high coefficient chip-scale optical waveguide technologies. Note: In FY 2006, effort moves to advanced photonic component technology for space-based sensors thrust in this Project. | 0.236 | 0.335 | 0.000 | 0.000 |
| (U) In FY 2004: Fabricated, tested, and evaluated efficient, high coefficient chip-scale optical waveguide technology for mixed signal component subsystems. | | | | |
| (U) In FY 2005: Test and evaluate efficient, high coefficient chip-scale optical waveguide technology for mixed signal component subsystems. | | | | |
| (U) In FY 2006: Not Applicable. | | | | |
| (U) In FY 2007: Not Applicable. | | | | |

| Exhibit R-2a, RDT&E Project Justification | | | DATE: February 2005 |
|---|---|---|---|
| BUDGET ACTIVITY: 02 Applied Research | PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE: 5028 Space Sensors, Photonics & RF Proc | |

| | | | | | |
|---|---|---|---|---|---|
| (U) | | | | | |
| (U) | MAJOR THRUST: Perform independent modeling, test, and evaluation for space-based sensors. Note: In FY 2006, effort moves to advanced photonic component technology for space-based sensors thrust in this Project. | 0.236 | 0.183 | 0.000 | 0.000 |
| (U) | In FY 2004: Applied the results of modeling, test, and evaluation for space-qualified photonic components and integrated electro-optical devices for space-based sensors to component architectures for high data rate space sensors and communication systems. | | | | |
| (U) | In FY 2005: Design and develop photonic digital and analog mixed signal multi-gigahertz component architectures for high data rate space sensors and communication systems. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Study adaptive processing techniques for large, multi-mission, space-based conformal arrays. | 2.671 | 1.071 | 1.077 | 2.967 |
| (U) | In FY 2004: Studied and analyzed adaptive processing techniques for large, multi-mission, space-based, adaptive conformal arrays. | | | | |
| (U) | In FY 2005: Develop adaptive processing techniques suitable for implementation on space-qualified computing architectures for multi-intelligence Intelligence, Surveillance, and Reconnaissance (ISR) sensing from space-based platforms. | | | | |
| (U) | In FY 2006: Continue to develop adaptive processing techniques suitable for implementation on space-qualified computing architectures for multi-intelligence ISR sensing from space-based platforms. Study signal processing methods and novel adaptive transmit waveform techniques for a space surveillance platform. | | | | |
| (U) | In FY 2007: Evaluate adaptive processing techniques suitable for implementation on space-qualified computing architectures for multi-intelligence ISR sensing from space-based platforms. Develop signal processing methods and novel adaptive transmit waveform techniques for a space surveillance platform. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop advance photonic component technology for space-base sensors that focuses on improving performance and reducing size, mass, and prime power. Supports ISR capability. Note: In FY 2006, photonics technology efforts move into this thrust from previous major thrusts in this Project. | 0.000 | 0.000 | 0.864 | 1.134 |
| (U) | In FY 2004: Not Applicable. | | | | |
| (U) | In FY 2005: Not Applicable. | | | | |
| (U) | In FY 2006: Develop and demonstrate photonic component technology enabling low loss true time delay | | | | |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5028 Space Sensors, Photonics & RF Proc |

for wideband phased array applications

(U) In FY 2007: Develop and model a photonic metrology architecture for large area antennas.

| | | | | |
|---|---|---|---|---|
| (U) Total Cost | 3.703 | 1.839 | 1.941 | 4.101 |

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

| | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| (U) Related Funding: | | | | | | | | | | |
| (U) PE 0602204F, Aerospace Sensors. | | | | | | | | | | |
| (U) PE 0603203F, Advanced Aerospace Sensors. | | | | | | | | | | |
| (U) PE 0603500F, Multi-Disciplinary Adv Dev Space Technology. | | | | | | | | | | |
| (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication. | | | | | | | | | | |

**(U) D. Acquisition Strategy**

Not Applicable.

# Exhibit R-2a, RDT&E Project Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

PROJECT NUMBER AND TITLE: 5029 Space Sensor & CM Tech

| Cost ($ in Millions) | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 5029 Space Sensor & CM Tech | 8.064 | 5.167 | 1.111 | 4.482 | 6.419 | 5.691 | 5.783 | 5.863 | Continuing | TBD |
| Quantity of RDT&E Articles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

**(U) A. Mission Description and Budget Item Justification**

This project focuses on developing processes and techniques for electronic and electromagnetic signal processing for ISR space sensor applications. This project develops the baseline technologies required to manage and perform on-board space sensor information fusion for timely and comprehensive communications and situational awareness. Through modeling and simulation, this project develops and evaluates innovative electromagnetic and electronic countermeasures for space applications.

| **(U) B. Accomplishments/Planned Program ($ in Millions)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| (U) MAJOR THRUST: Develop compact, affordable, multi-function receiver/exciter and phased array components for communications, Global Positioning System (GPS), radar, electronic warfare, and other ISR space sensors. | 1.761 | 0.000 | 0.000 | 0.000 |
| (U) In FY 2004: Fabricated and tested compact, affordable, multifunction receiver/exciter and phased array components for communications, GPS, radar, electronic warfare, and other ISR space sensors. Evaluated integrating these components into operational radar and electronic warfare digital receiver/exciter modules. Demonstrated a feasible architecture for performing wideband direct digital synthesis from aerospace platforms. Performed a component evaluation of an electronic/photonic digital receiver for Moving Target Indication and Synthetic Aperture Radar applications. | | | | |
| (U) In FY 2005: Not Applicable. Effort terminated due to higher Air Force priorities. | | | | |
| (U) In FY 2006: Not Applicable. | | | | |
| (U) In FY 2007: Not Applicable. | | | | |
| (U) | | | | |
| (U) MAJOR THRUST: Develop and integrate microwave technologies for advanced radio frequency apertures and phased array antennas used in military ISR space sensors. Note: In FY 2006, effort moves to array antenna subsytems and advanced materials thrust in this Project. | 0.918 | 1.700 | 0.000 | 0.000 |
| (U) In FY 2004: Developed the proof of concept of transmitter and receiver (T/R) channels that are able to withstand radiation, limited or no active cooling, and strong, undesired electromagnetic radiation. | | | | |
| (U) In FY 2005: Develop T/R channels that are able to withstand radiation, limited or no active cooling, and strong, undesired electromagnetic radiation. | | | | |
| (U) In FY 2006: Not Applicable. | | | | |
| (U) In FY 2007: Not Applicable. | | | | |
| (U) | | | | |

| Exhibit R-2a, RDT&E Project Justification | | | DATE February 2005 |
|---|---|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5029 Space Sensor & CM Tech | |

| | | | | | |
|---|---|---|---|---|---|
| (U) | MAJOR THRUST: Develop X-band sub-assemblies based on flexible RF membranes. Note: In FY 2006, effort moves to array antenna subsytems and advanced materials thrust in this Project. | 0.411 | 0.503 | 0.000 | 0.000 |
| (U) | In FY 2004: Developed a large area (>0.5 m2) active aperture based on flexible RF membranes that lowers the assembly costs and mass over conventional phased arrays by an order of magnitude. | | | | |
| (U) | In FY 2005: Develop and investigate approaches and techniques to produce large area (>40 m2) active spaceborne aperture using advanced highly integrated and lightweight RF subassemblies. Demonstrate ten-fold reduction in assembly cost and aperture mass. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop two- and three-dimensional interconnects for space applications. Note: In FY 2006, effort moves to array antenna subsytems and advanced materials thrust in this Project. | 0.329 | 0.452 | 0.000 | 0.000 |
| (U) | In FY 2004: Developed mixed signal receiver/processor multi-functionality on flexible RF membranes using advanced two-dimensional and three-dimensional interconnects. | | | | |
| (U) | In FY 2005: Perform environmental testing of the multi-functional flex assemblies two-dimensional and three-dimensional interconnect approaches to determine their applicability for operation in a hostile environment. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop techniques to accurately predict scattering phenomenology associated with electromagnetic radiation. Note: In FY 2005, effort is complete. | 0.426 | 0.552 | 0.000 | 0.000 |
| (U) | In FY 2004: Further refined the accuracy of exploitation of the scattering phenomenology associated with electromagnetic radiation returned from objects or backgrounds when viewed from space. | | | | |
| (U) | In FY 2005: Complete refinement of the accuracy of exploitation of the scattering phenomenology associated with electromagnetic radiation returned from objects or backgrounds when viewed from space. Evaluate performance and enhancements to target recognition using these techniques. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop space-qualified precision time, position, and velocity sensors capable of operating in jamming environments enabling multiple platform sensor-to-shooter operations. Note: In FY 2006, effort is complete. | 2.437 | 1.623 | 0.344 | 0.000 |
| (U) | In FY 2004: Designed robust precision time, position, and velocity sensor technologies for | | | | |

| Exhibit R-2a, RDT&E Project Justification | | | DATE February 2005 |
|---|---|---|---|
| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5029 Space Sensor & CM Tech** | |

| | | | | | |
|---|---|---|---|---|---|
| | multi-platform sensor-to-shooter network-centric engagement. Developed synergistic global positioning system jamming mitigation techniques for operation in hostile RF environments. | | | | |
| (U) | In FY 2005: Develop robust precision time, position, and velocity sensor technologies for multi-platform network centric engagement. Evaluate synergistic global positioning system jamming mitigation techniques for operation in hostile RF environments. | | | | |
| (U) | In FY 2006: Demonstrate highly accurate and robust precision time, position, and velocity sensor techniques for space-based applications. Develop constructive systems engineering model to assess space-based assured reference techniques in terms of measures of performance and warfighter utility. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop technology to enable affordable upgrades to space-qualified RF signal receivers. Note: In FY 2006, effort terminated due to higher Air Force priorities. | 0.260 | 0.337 | 0.000 | 0.000 |
| (U) | In FY 2004: Continued modeling threat identification algorithms for next generation threat warning receivers. Continue evaluating state-of-the-art digital and software receiver techniques for radar, electronic warfare, and narrowband space applications. | | | | |
| (U) | In FY 2005: Further model threat identification algorithms for next generation threat warning receivers. Evaluate state-of-the-art digital and software receiver techniques for radar, electronic warfare, and narrowband space applications. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop affordable radar technologies. | 1.522 | 0.000 | 0.000 | 0.000 |
| (U) | In FY 2004: Further developed a model system of the Active Electronic Scanned Antenna and On-Board Processor to demonstrate the technical readiness of the most critical element of an affordable radar. Note: In FY 2004, efforts completed. | | | | |
| (U) | In FY 2005: Not Applicable. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Not Applicable. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST: Develop advanced active phased array antenna subsystems to meet the unique requirements of affordable space based sensing including the restrictions on mass, size, power. Utilize advanced materials, to demonstrate low-mass, low cost, reliable and scalable apertures. Supports intelligence, surveillance, and reconnaissance capability. Note: In FY 2006, efforts on advanced RF apertures, membranes, and interconnects move into this thrust from previous major thrusts in this Project. | 0.000 | 0.000 | 0.767 | 0.352 |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5029 Space Sensor & CM Tech |

(U) In FY 2004: Not Applicable.
(U) In FY 2005: Not Applicable.
(U) In FY 2006: Develop low-mass shallow-depth microwave antenna panels with integrated active elements and low RF distribution loss.
(U) In FY 2007: Demonstrate low-mass scalable tiles/panels with advanced thermal management and improved efficiency for active components
(U)

| | | | | | |
|---|---|---|---|---|---|
| (U) | MAJOR THRUST: Develop hybrid space-based sensor solutions and reduce associated technology risks. Develop algorithms to solve signal processing challenges specific to space-based sensor platforms. Note: In FY 2007, space-based sensor platform technology efforts, previously performed under other major thrusts in the Project, were placed here to show greater emphasis. | 0.000 | 0.000 | 0.000 | 4.130 |
| (U) | In FY 2004: Not Applicable. | | | | |
| (U) | In FY 2005: Not Applicable. | | | | |
| (U) | In FY 2006: Not Applicable. | | | | |
| (U) | In FY 2007: Initiate identification and development specific techniques and technologies to further expand the capabilities of space-based sensor platforms. | | | | |
| (U) | Total Cost | 8.064 | 5.167 | 1.111 | 4.482 |

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

| | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| (U) Related Activities: | | | | | | | | | | |
| (U) PE 0602204F, Aerospace Sensors. | | | | | | | | | | |
| (U) PE 0603203F, Advanced Aerospace Sensors. | | | | | | | | | | |
| (U) PE 0603500F, Multi-Disciplinary Adv Dev Space Technology. | | | | | | | | | | |
| (U) This project has been coordinated through the Reliance process to harmonize efforts and eliminate duplication. | | | | | | | | | | |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5029 Space Sensor & CM Tech |

**(U) D. Acquisition Strategy**

Not Applicable.

# Exhibit R-2a, RDT&E Project Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

PROJECT NUMBER AND TITLE: 5081 Space Antennas Tech

| Cost ($ in Millions) | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 5081 Space Antennas Tech | 1.034 | 1.394 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | Continuing | TBD |
| Quantity of RDT&E Articles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

Note: In FY 2006, efforts in this project move to Project 5082 in this PE.

**(U) A. Mission Description and Budget Item Justification**

This project develops the technology base for satellite antenna technology and affordable terminal technology for communications. Enabling technologies developed under this project for satellite terminals will focus on significantly lowering the life cycle cost communications system ownership, while increasing performance. The project will include new approaches to optical and RF communications transmit and receive technologies to improve network communications performance.

| **(U) B. Accomplishments/Planned Program ($ in Millions)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| (U) MAJOR THRUST: Develop and demonstrate heterogeneous, seamless, secure, self-configuring, high capacity air/space/surface wireless network, ensuring applicability relevance to space missions. Develop variable data rate, networked data link hardware and the associated RF ground stations for such wireless networks. | 1.034 | 1.394 | 0.000 | 0.000 |
| (U) In FY 2004: Developed variable data rate, networked data link hardware and the associated RF ground stations. Designed and developed Optical Local Area Networks (LAN) and gateways for optical communications between space and airborne assets/platforms. | | | | |
| (U) In FY 2005: Continue development of variable data rate, networked data link hardware and the associated RF ground stations. Continue Optical LAN and gateways for optical communications between space and airborne assets/platforms. Initiate characterization and development of industry standard single mode optical communications bus for airborne platforms and air-to-air or air-to-ground-to-air RF and laser networked communications. | | | | |
| (U) In FY 2006: Not Applicable. | | | | |
| (U) In FY 2007: Not Applicable. | | | | |
| (U) Total Cost | 1.034 | 1.394 | 0.000 | 0.000 |

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

| | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| (U) PE 0602204F, Aerospace Sensors. | | | | | | | | | | |
| (U) PE 0603203F, Advanced Aerospace Sensors. | | | | | | | | | | |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5081 Space Antennas Tech** |

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

PE 0603500F,
(U) Multi-Disciplinary Adv Dev
Space Technology.
This project has been
coordinated through the
(U) Reliance process to
harmonize efforts and
eliminate duplication.

**(U) D. Acquisition Strategy**

Not Applicable.

# Exhibit R-2a, RDT&E Project Justification

DATE: February 2005

BUDGET ACTIVITY: 02 Applied Research

PE NUMBER AND TITLE: 0602500F MULTI-DISCIPLINARY SPACE TECH

PROJECT NUMBER AND TITLE: 5082 Optical Networking Tech

| Cost ($ in Millions) | | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5082 | Optical Networking Tech | 5.942 | 7.522 | 8.799 | 11.163 | 17.404 | 12.791 | 9.578 | 9.947 | Continuing | TBD |
| | Quantity of RDT&E Articles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

Note: In FY 2006, efforts in Project 5081 move to this project and the Air Force increased emphasis on developing optical networks for space-based applications.

**(U) A. Mission Description and Budget Item Justification**

This project develops the technology base for the next generation of ultra-wide- bandwidth, multi-channeled, air and space-based communications networks on and between platforms. As the application of laser-based, point-to-point communications between satellites emerges, air and space-based optical networks, whose communications capacities are thousands of times greater than current communications satellites, become a realistic possibility. This project will assess and adapt the emerging communication and information technologies, for applications in air and space. This project will explore technologies for implementing photonic chip scale optical Code Division Multiple Access (CDMA) and Wavelength Division Multiplexed (WMD) transceivers and prototype networks, built to demonstrate the benefits associated with the advanced fiber optic, wireless, platform, and satellite networks that can be built from them. This project will develop and demonstrate technology to integrate current Radio Frequency with high data rate Optical LASER communications, along with network management techniques, tools and software to support them. These technologies have potential applications in specific military systems including reliable, high bandwidth, jam-resistant communications at the theater level, and multiplexing of multiple DoD users onto a common networking infrastructure for reduced manning and logistics.

| **(U) B. Accomplishments/Planned Program ($ in Millions)** | FY 2004 | FY 2005 | FY 2006 | FY 2007 |
|---|---|---|---|---|
| (U) MAJOR THRUST: Develop and assess optical network technologies for application in the space environment. | 1.983 | 1.576 | 1.535 | 1.532 |

(U) In FY 2004: Assessed, explored, and adapted the emerging communication and information technologies being developed for next-generation Internet, for applications in space.

(U) In FY 2005: Complete assessment of next generation Internet arrayed-waveguide grating technologies for application in the space environment. Initiate design and development of a multi-path interconnection network that provides for redundancy, fault tolerance, self-routing and non-blocking switching required for space-based networks. Develop transmission technology and control concepts to support optically networked communications.

(U) In FY 2006: Complete design and development of a multi-path interconnection network that provides for redundancy, fault tolerance, self-routing and non-blocking switching required for air and space-based networks. Initiate demonstration of highly integrated multi-gigabit optical network with 4 x 4 optical data router and optical backbone interface chips.

(U) In FY 2007: Complete demonstration of highly integrated multi-gigabit optical network with 4 x 4 optical data router and optical backbone interface chips. Initiate demonstration of highly integrated multi-gigabit optical network with 16 x 16 optical data router and optical backbone interface chips.

(U)

| Exhibit R-2a, RDT&E Project Justification | | | DATE February 2005 |
|---|---|---|---|
| BUDGET ACTIVITY<br>02 Applied Research | PE NUMBER AND TITLE<br>0602500F MULTI-DISCIPLINARY SPACE TECH | PROJECT NUMBER AND TITLE<br>5082 Optical Networking Tech | |

| | | | | | |
|---|---|---|---|---|---|
| (U) | MAJOR THURST: Develop and assess existing and emerging Optical CDMA and WDM modulation schemes and protocols for use in space-based optical networks. | 2.055 | 1.972 | 3.044 | 3.065 |
| (U) | In FY 2004: In conjunction with industry and academia, developed or adapted appropriate standards to ensure the evolution of open systems architecture for space-based optical networks. | | | | |
| (U) | In FY 2005: Develop or adapt, along with industry and academia, appropriate standards to ensure the evolution of open systems architecture for space-based optical networks. Investigate emerging terrestrial optical burst switching and optical label switching protocols for applicability to space-based optical networks. | | | | |
| (U) | In FY 2006: Demonstrate industry standard single mode optical communications bus interface chip for airborne platforms. Initiate design and development of optical burst switching and optical label switching protocols for applicability to air and space-based optical networks. Initiate flight demonstration of industry standard single mode optical communications bus interface chip for airborne platforms. | | | | |
| (U) | In FY 2007: Continue design and development of optical burst switching and optical label switching protocols for applicability to air and space-based optical networks. Continue flight demonstration of industry standard single mode optical communications bus interface chip for airborne platforms. | | | | |
| (U) | | | | | |
| (U) | MAJOR THURST: Develop and demonstrate heterogeneous, seamless, secure, self-configuring high capacity air/space/surface wireless networks that integrate current RF with high data rate Optical Laser communications. Note: In FY 2005, greater emphasis was placed on laser communication technologies. | 0.000 | 0.324 | 4.220 | 6.566 |
| (U) | In FY 2004: Not Applicable. | | | | |
| (U) | In FY 2005: Develop variable data rate, networked data link RF/optical hardware and their associated ground stations. | | | | |
| (U) | In FY 2006: Initiate design and development of waveform, coding, management, and atmospheric mitigation technologies for a combined RF/laser communications brassboard. Continue characterization and development of industry standard single mode optical communications bus for airborne platforms and air to air or air to ground RF and laser networked communication. | | | | |
| (U) | In FY 2007: Continue design and development of waveform, coding, management, and atmospheric mitigation technologies for a combined RF/laser communications terminal. Demonstrate development of industry standard single mode optical communications bus for airborne platforms and air to air or air to ground RF and laser networked communication. | | | | |
| (U) | | | | | |
| (U) | MAJOR THRUST/CONGRESSIONAL ADD: Establish and maintain a capability to characterize, evaluate, and optimize network components and technologies for space applications. Note: Includes | 1.904 | 2.659 | 0.000 | 0.000 |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5082 Optical Networking Tech** |

Congressional Add funding of $1.0 in FY 2004 and $1.7 million in FY 2005. Additionally, program efforts complete in FY 2005.

(U) In FY 2004: Developed photonic chip scale optically implemented CDMA and WDM transceivers and laboratory network into a capability to characterize, evaluate, and optimize optical network components and technologies for space applications.

(U) In FY 2005: Develop and evaluate performance of passive and active optical/electronic chip-scale networking components (transmitters, receivers, switches) for CDMA and WDM on board networks operating at gigabits per second. Develop and demonstrate innovative technologies, such as 16-channel WDM laser array on one chip, 16-channel WDM array receivers on one chip, and compact high-speed optical transmission subsystems, that can provide the Air Forces with a secure means of transmitting high-speed data information (imagery, video, audio and text ) from various platforms, while decreasing the size, power, and weight.

(U) In FY 2006: Not Applicable.

(U) In FY 2007: Not Applicable.

(U)

| | | | | | |
|---|---|---|---|---|---|
| (U) | CONGRESSIONAL ADD: Internet Protocol Commanding of Satellites. | 0.000 | 0.991 | 0.000 | 0.000 |

(U) In FY 2004: Not Applicable.

(U) In FY 2005: Develop and demonstrate technology allowing a satellite to be commanded by a field commander for obtaining near-real-time sensor data of interest. Develop an end-to-end architecture for command and control of a satellite based on a High Assurance Internet Protocol Encryption (HAIPE) architecture, where the interface of the HAIPE command and control system with the ground and Space payload will be fully defined.

(U) In FY 2006: Not Applicable.

(U) In FY 2007: Not Applicable.

| | | | | | |
|---|---|---|---|---|---|
| (U) | Total Cost | 5.942 | 7.522 | 8.799 | 11.163 |

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

| | FY 2004 Actual | FY 2005 Estimate | FY 2006 Estimate | FY 2007 Estimate | FY 2008 Estimate | FY 2009 Estimate | FY 2010 Estimate | FY 2011 Estimate | Cost to Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| (U) PE 0602702F, Command, Control, and Communications. | | | | | | | | | | |
| (U) PE 0603789F, C3I Advanced Development. | | | | | | | | | | |

| Exhibit R-2a, RDT&E Project Justification | | DATE February 2005 |
|---|---|---|
| BUDGET ACTIVITY<br>**02 Applied Research** | PE NUMBER AND TITLE<br>**0602500F MULTI-DISCIPLINARY SPACE TECH** | PROJECT NUMBER AND TITLE<br>**5082 Optical Networking Tech** |

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

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

**(U) D. Acquisition Strategy**

Not Applicable.